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This is a request for filing a PROVISIONAL APPLICATION under 37 CFR 1.53(c).

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TITLE OF THE INVENTION

MODAFINIL COMPOSITIONS

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Respectfully submitted,

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MODAFINIL COMPOSITIONS

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MODAFINIL COMPOSITIONS

FIELD OF THE INVENTION

The present invention relates to API-containing compositions, pharmaceutical compositions comprising such APIs, and methods for preparing the same.

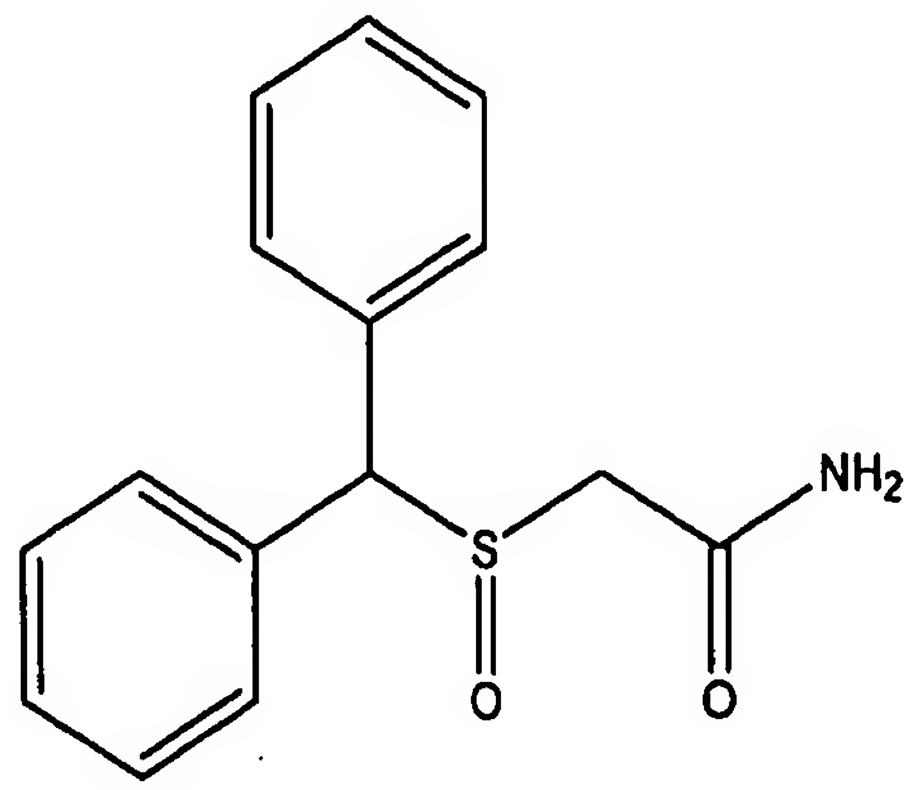
BACKGROUND OF THE INVENTION

Active pharmaceutical ingredients (API or APIs (plural)) in pharmaceutical compositions can be prepared in a variety of different forms. Such APIs can be prepared so as to have a variety of different chemical forms including chemical derivatives or salts. Such APIs can also be prepared to have different physical forms. For example, the APIs may be amorphous, may have different crystalline polymorphs, or may exist in different solvation or hydration states. By varying the form of an API, it is possible to vary the physical properties thereof. For example, crystalline polymorphs typically have different solubilities from one another, such that a more thermodynamically stable polymorph is less soluble than a less thermodynamically stable polymorph. Pharmaceutical polymorphs can also differ in properties such as shelf-life, bioavailability, morphology, vapour pressure, density, colour, and compressibility. Accordingly, variation of the crystalline state of an API is one of many ways in which to modulate the physical properties thereof. .

It would be advantageous to have new forms of these APIs that have improved properties, in particular, as oral formulations. Specifically, it is desirable to identify improved forms of APIs that exhibit significantly improved properties including increased aqueous solubility and stability. Further, it is desirable to improve the processability, or preparation of pharmaceutical formulations. For example, needle-like crystal forms or habits of APIs can cause aggregation, even in compositions where the API is mixed with other substances, such that a non-uniform mixture is obtained. It is also desirable to increase the dissolution rate of API-containing pharmaceutical compositions in water, increase the bioavailability of orally-administered compositions, and provide a more rapid onset to therapeutic effect. It is also desirable to have a form of

the API which, when administered to a subject, reaches a peak plasma level faster, has a longer lasting therapeutic plasma concentration, and higher overall exposure when compared to equivalent amounts of the API in its presently-known form.

Modafinil, an API used to treat subjects with narcolepsy, is practically insoluble in water. Modafinil(CAS Registry Number: 68693-11-8) is represented by the structure (I):



(I)

It would be advantageous to have new forms of modafinil that have improved properties, in particular, as oral formulations. Specifically, it is desirable to identify improved forms of modafinil that exhibit significantly increased aqueous solubilities and both chemical and form stability. It is also desirable to increase the dissolution rate of API-containing pharmaceutical compositions in water, increase the bioavailability of orally-administered compositions, and provide a more rapid onset to therapeutic effect. It is also desirable to have a form of the API which, when administered to a subject, reaches a peak plasma level faster and/or has a longer lasting plasma concentration and higher overall exposure at high doses when compared to equivalent amounts of the API in its presently-known form.

SUMMARY OF THE INVENTION

It has now been found that co-crystals and solvates of modafinil can be obtained which have different properties as compared to the free form of the API.

Accordingly, in a first aspect, the present invention provides a co-crystal of modafinil, wherein the co-crystal former is an ether, thioether, alcohol, thiol, aldehyde, ketone, thioketone, nitrate ester, phosphate ester, thiophosphate ester, ester, thioester, sulfate ester, carboxylic acid, phosphonic acid, phosphinic acid, sulfonic acid, amide, primary amine, secondary amine, ammonia, tertiary amine, sp2 amine, thiocyanate, cyanamide, oxime, nitrile, diazo, organohalide, nitro, S-heterocyclic ring, thiophene, N-heterocyclic ring, pyrrole, O-heterocyclic ring, furan, epoxide, peroxide, hydroxamic acid, imidazole, or pyridine.

The invention further provides a pharmaceutical composition comprising a co-crystal of modafinil. Typically, the pharmaceutical composition further comprises one or more pharmaceutically-acceptable carriers, diluents or excipients. Pharmaceutical compositions according to the invention are described in further detail below.

In a further aspect, the present invention provides a process for the preparation of a co-crystal of modafinil, which comprises:

(1) providing modafinil;

(2) providing a co-crystal former which has at least one functional group selected from the group consisting of ether, thioether, alcohol, thiol, aldehyde, ketone, thioketone, nitrate ester, phosphate ester, thiophosphate ester, ester, thioester, sulfate ester, carboxylic acid, phosphonic acid, phosphinic acid, sulfonic acid, amide, primary amine, secondary amine, ammonia, tertiary amine, sp2 amine, thiocyanate, cyanamide, oxime, nitrile, diazo, organohalide, nitro, S-heterocyclic ring, thiophene, N-heterocyclic ring, pyrrole, O-heterocyclic ring, furan, epoxide, peroxide, hydroxamic acid, imidazole, or pyridine;

(3) grinding, heating, co-subliming, co-melting, or contacting in solution modafinil with the co-crystal former under crystallization conditions, so as to form a solid phase; and

(4) isolating co-crystals comprising modafinil and the co-crystal former.

In a further aspect, the present invention provides a process for modulating the solubility of modafinil for use in a pharmaceutical composition, which process comprises:

(1) providing modafinil;

(2) providing a co-crystal former which has at least one functional group selected from the group consisting of ether, thioether, alcohol, thiol, aldehyde, ketone, thioketone, nitrate ester, phosphate ester, thiophosphate ester, ester, thioester, sulfate ester, carboxylic acid, phosphonic acid, phosphinic acid, sulfonic acid, amide, primary amine, secondary amine, ammonia, tertiary amine, sp2 amine, thiocyanate, cyanamide, oxime, nitrile, diazo, organohalide, nitro, S-heterocyclic ring, thiophene, N-heterocyclic ring, pyrrole, O-heterocyclic ring, furan, epoxide, peroxide, hydroxamic acid, imidazole, or pyridine;

(3) grinding, heating, co-subliming, co-melting, or contacting in solution modafinil with the co-crystal former under crystallization conditions, so as to form a solid phase; and

(4) isolating co-crystals comprising modafinil and the co-crystal former.

In a further aspect, the present invention provides a process for modulating the dissolution of modafinil, whereby the aqueous dissolution rate or the dissolution rate in simulated gastric fluid or in simulated intestinal fluid, or in a solvent or plurality of solvents is increased, which process comprises:

(1) grinding, heating, co-subliming, co-melting, or contacting in solution modafinil with a co-crystal former under crystallization conditions, so as to form a co-crystal of modafinil and the co-crystal former; and

(2) isolating co-crystals comprising modafinil and the co-crystal former.

In one embodiment, the dissolution of modafinil is increased.

In a further aspect, the present invention provides a process for modulating the bioavailability of modafinil, whereby the AUC is increased, the time to T_{max} is reduced,

the length of time the concentration of modafinil is above ½ T_{max} is increased, or C_{max} is increased, which process comprises:

(1) grinding, heating, co-subliming, co-melting, or contacting in solution modafinil with a co-crystal former under crystallization conditions, so as to form a co-crystal of modafinil and the co-crystal former; and

(2) isolating co-crystals comprising modafinil and the co-crystal former.

In a further aspect, the present invention provides a process for modulating the dose response of modafinil for use in a pharmaceutical composition, which process comprises:

(1) providing modafinil;

(2) providing a co-crystal former which has at least one functional group selected from the group consisting of ether, thioether, alcohol, thiol, aldehyde, ketone, thioketone, nitrate ester, phosphate ester, thiophosphate ester, ester, thioester, sulfate ester, carboxylic acid, phosphonic acid, phosphinic acid, sulfonic acid, amide, primary amine, secondary amine, ammonia, tertiary amine, sp2 amine, thiocyanate, cyanamide, oxime, nitrile, diazo, organohalide, nitro, S-heterocyclic ring, thiophene, N-heterocyclic ring, pyrrole, O-heterocyclic ring, furan, epoxide, peroxide, hydroxamic acid, imidazole, or pyridine;

(3) grinding, heating, co-subliming, co-melting, or contacting in solution modafinil with the co-crystal former under crystallization conditions, so as to form a solid phase; and

(4) isolating co-crystals comprising modafinil and the co-crystal former.

In a still further aspect the present invention provides a process for improving the stability of modafinil (as compared to a reference form such as its free form), which process comprises:

(1) grinding, heating, co-subliming, co-melting, or contacting in solution modafinil with a co-crystal former under crystallization conditions, so as to form a co-crystal of modafinil and the co-crystal former; and

(2) isolating co-crystals comprising modafinil and the co-crystal former.

In a still further aspect the present invention provides a process for modifying the morphology of modafinil, which process comprises:

(1) grinding, heating, co-subliming, co-melting, or contacting in solution modafinil with a co-crystal former under crystallization conditions, so as to form a co-crystal of the modafinil and the co-crystal former; and

(2) isolating co-crystals comprising the modafinil and the co-crystal former.

In a still further aspect, the present invention therefore provides a process of screening for co-crystal compounds, which comprises:

(1) providing (*i*) modafinil and (*ii*) a co-crystal former; and

(2) screening for co-crystals of modafinil with a co-crystal former by subjecting each combination of modafinil and co-crystal former to a procedure comprising:

(a) grinding, heating, co-subliming, co-melting, or contacting in solution modafinil with the co-crystal former under crystallization conditions so as to form a solid phase; and

(b) isolating co-crystals comprising modafinil and the co-crystal former.

An alternative embodiment is drawn to a process of screening for co-crystal compounds, which comprises:

(1) providing (*i*) modafinil and (*ii*) a plurality of different co-crystal formers; and

(2) screening for co-crystals of modafinil with co-crystal formers by subjecting each combination of modafinil and co-crystal former to a procedure comprising:

(a) grinding, heating, co-subliming, co-melting, or contacting in solution modafinil with the co-crystal former under crystallization conditions so as to form a solid phase; and

(b) isolating co-crystals comprising modafinil and the co-crystal former.

In a further aspect, the present invention provides a co-crystal composition comprising a co-crystal, wherein said co-crystal comprises modafinil and a co-crystal former. In further embodiments the co-crystal has an improved property as compared to the free form (which includes hydrates and solvates). In further embodiments, the improved property is selected from the group consisting of: increased solubility, increased dissolution, increased bioavailability, increased dose response, or other property described herein.

The processes according to the present invention may each comprise a further step or steps in which the modafinil co-crystal produced thereby is incorporated into a pharmaceutical composition.

In a further embodiment, the present invention provides a novel polymorph of R-(-)-modafinil. In a specific embodiment, the present invention provides Forms I, II, III, IV, and V of R-(-)-modafinil. The present invention also provides a method of making a polymorph of R-(-)-modafinil.

In a further embodiment, the present invention provides a method of making a polymorph of R-(-)-modafinil, comprising:

(a) providing R-(-)-modafinil;

(b) crystallizing the polymorph of R-(-)-modafinil from an appropriate solvent.

In a further embodiment, a polymorph of R-(-)-modafinil is crystallized from an organic solvent. In a particular embodiment, the organic solvent is ethanol. In another embodiment, a mixed solvent system is used to crystallize a polymorph of R-(-)-modafinil. Mixed solvent systems can be, for example, ethanol and isopropyl alcohol, or ethyl acetate and ethanol. In a further embodiment, the crystallization in step (b) is

completed via thermal recrystallization. In a further embodiment, the crystallization in step (b) is completed via evaporation of the solvent.

In a still further aspect of the invention, a method is provided for treating a subject, preferably a human subject, suffering from excessive daytime sleepiness associated with narcolepsy, multiple sclerosis related fatigue, infertility, eating disorders, attention deficit hyperactivity disorder (ADHD), Parkinson's disease, incontinence, sleep apnea, or myopathies where modafinil is an effective active pharmaceutical for said disorder. The method comprises administering to the subject a therapeutically-effective amount of a co-crystal or a solvate comprising modafinil.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1- PXRD diffractogram of a co-crystal comprising modafinil and malonic acid.
Figure 2- DSC thermogram of a co-crystal comprising modafinil and malonic acid.
Figure 3- TGA thermogram of a co-crystal comprising modafinil and malonic acid.
Figure 4A and 4B- Raman spectrum of a co-crystal comprising modafinil and malonic acid (Figure 4A), and three Raman spectra of modafinil (bottom spectrum), malonic acid (middle spectrum), and a co-crystal comprising modafinil and malonic acid (top spectrum) (Figure 4B).
Figure 5A and 5B- Infrared spectrum of a co-crystal comprising modafinil and malonic acid (Figure 5A), and three Infrared spectra of modafinil (top spectrum), malonic acid (middle spectrum), and a co-crystal comprising modafinil and malonic acid (bottom spectrum) (Figure 5B).
Figure 6- PXRD diffractogram of a co-crystal comprising modafinil and malonic acid.
Figure 7- Packing diagram for modafinil:malonic acid co-crystal.
Figures 8A and 8B- PXRD diffractograms of a co-crystal comprising modafinil and glycolic acid, background removed and as collected, respectively.
Figures 9A and 9B- PXRD diffractograms of a co-crystal comprising modafinil and maleic acid, background removed and as collected, respectively.
Figure 10- PXRD diffractogram of a co-crystal comprising modafinil and L-tartaric acid.

Figure 11- PXRD diffractogram of a co-crystal comprising modafinil and citric acid.

Figures 12A and 12B- PXRD diffractogram of a co-crystal comprising modafinil and succinic acid, background removed and as collected, respectively.

Figure 13- DSC thermogram of a co-crystal comprising modafinil and succinic acid.

Figure 14- Packing diagram of a co-crystal comprising modafinil and succinic acid.

Figure 15- PXRD diffractogram of a co-crystal comprising modafinil and DL-tartaric acid.

Figure 16- PXRD diffractogram of a co-crystal comprising modafinil and fumaric acid (Form I).

Figure 17- Packing diagram of a co-crystal comprising modafinil and fumaric acid (Form I).

Figure 18- PXRD diffractogram of a co-crystal comprising modafinil and fumaric acid (Form II).

Figure 19- PXRD diffractogram of a co-crystal comprising modafinil and gentisic acid.

Figure 20- PXRD diffractogram of a co-crystal comprising modafinil and oxalic acid.

Figure 21- PXRD diffractogram of a co-crystal comprising modafinil and 1-hydroxy-2-naphthoic acid.

Figure 22- PXRD diffractogram of a co-crystal comprising R-(-)-modafinil and malonic acid.

Figure 23- DSC thermogram of a co-crystal comprising R-(-)-modafinil and malonic acid.

Figure 24- PXRD diffractogram of a co-crystal comprising R-(-)-modafinil and succinic acid.

Figure 25- DSC thermogram of a co-crystal comprising R-(-)-modafinil and succinic acid.

Figure 26- PXRD diffractogram of a co-crystal comprising R-(-)-modafinil and citric acid.

Figure 27- DSC thermogram of a co-crystal comprising R-(-)-modafinil and citric acid.

Figure 28- PXRD diffractogram of a co-crystal comprising R-(-)-modafinil and DL-tartaric acid.

Figure 29- DSC thermogram of a co-crystal comprising R-(-)-modafinil and DL-tartaric acid.

Figure 30- PXRD diffractogram of a co-crystal comprising R-(-)-modafinil and 1-hydroxy-2-naphthoic acid.

Figure 31- DSC thermogram of a co-crystal comprising R-(-)-modafinil and 1-hydroxy-2-naphthoic acid.

Figure 32- PXRD diffractogram of a co-crystal comprising R-(-)-modafinil and lauric acid (bottom pattern).

Figure 33- DSC thermogram of a co-crystal comprising R-(-)-modafinil and lauric acid.

Figure 34- PXRD diffractogram of a co-crystal comprising R-(-)-modafinil and orotic acid.

Figure 35- DSC thermogram of a co-crystal comprising R-(-)-modafinil and orotic acid.

Figure 36- PXRD diffractogram of a solvate comprising modafinil and acetic acid.

Figure 37- TGA thermogram of a solvate comprising modafinil and acetic acid.

Figure 38- DSC thermogram of a solvate comprising modafinil and acetic acid.

Figure 39- Raman spectrum of a solvate comprising modafinil and acetic acid.

Figure 40- PXRD diffractogram of a solvate comprising modafinil and tetrahydrofuran.

Figure 41- PXRD diffractogram of a solvate comprising modafinil and 1,4-dioxane.

Figure 42- PXRD diffractogram of a solvate comprising modafinil and methanol.

Figure 43- TGA thermogram of a solvate comprising modafinil and methanol.

Figure 44- DSC thermogram of a solvate comprising modafinil and methanol.

Figure 45- PXRD diffractogram of a solvate comprising modafinil and nitromethane.

Figure 46- PXRD diffractogram of a solvate comprising modafinil and acetone.

Figure 47- PXRD diffractogram of a possible solvate comprising modafinil and acetone.

Figure 48- PXRD diffractogram of a possible solvate comprising modafinil and 1,2-dichloroethane.

Figure 49- PXRD diffractogram of a polymorph of modafinil (Form VII).

Figure 50- Stability plot of modafinil:malonic acid co-crystal over a 26 week period.

Figure 51- Closer view of stability plot of modafinil:malonic acid co-crystal over a 26 week period.

DETAILED DESCRIPTION OF THE INVENTION

The term "co-crystal" as used herein means a crystalline material comprised of two or more unique solids at room temperature, each containing distinctive physical characteristics, such as structure, melting point, and heats of fusion, with the exception that, if specifically stated, the API may be a liquid at room temperature. The co-crystals of the present invention comprise a co-crystal former H-bonded to modafinil or a derivative thereof. The co-crystal former may be H-bonded directly to modafinil or may be H-bonded to an additional molecule which is bound to modafinil. The additional molecule may be H-bonded to modafinil or bound ionically or covalently to modafinil. The additional molecule could also be a different API. Solvates of modafinil compounds that do not further comprise a co-crystal former are not co-crystals according to the present invention. The co-crystals may however, include one or more solvate molecules in the crystalline lattice. That is, solvates of co-crystals, or a co-crystal further comprising a solvent or compound that is a liquid at room temperature, is included in the present invention, but crystalline material comprised of only modafinil and one or more liquids (at room temperature) are not included in the present invention. Other modes of molecular recognition may also be present including, pi-stacking, guest-host complexation and van der Waals interactions. Of the interactions listed above, hydrogen-bonding is the dominant interaction in the formation of the co-crystal, (and a required interaction according to the present invention) whereby a non-covalent bond is formed between a hydrogen bond donor of one of the moieties and a hydrogen bond acceptor of the other. Hydrogen bonding can result in several different intermolecular configurations. For example, hydrogen bonds can result in the formation of dimers, linear chains, or cyclic structures. These configurations can further include extended (two-dimensional) hydrogen bond networks and isolated triads. An alternative embodiment provides for a co-crystal wherein the co-crystal former is a second API. In another embodiment, the co-crystal former is not an API. For purposes of the present invention, the chemical and physical properties of modafinil in the form of a co-crystal may be compared to a reference compound that is modafinil in a different form. The reference compound may be specified as a free form, or more specifically, an anhydrate

or hydrate of a free form, or more specifically, for example, a hemihydrate, monohydrate, dihydrate, trihydrate, quadrahydrate, pentahydrate; or a solvate of a free form. For example, the reference compound for modafinil in free form co-crystallized with a co-crystal former can be modafinil in free form. The reference compound may also be specified as crystalline or amorphous. The reference compound may also be specified as the most stable polymorph of the specified form of the reference compound.

The ratio of modafinil to co-crystal former may be stoichiometric or non-stoichiometric according to the present invention. Non-limiting examples such as, 1:1, 1:1.5, 1.5:1, 1:2, and 2:1 ratios of modafinil:co-crystal former are acceptable. In addition, co-crystals with vacancies within the crystalline lattice are included in the present invention. For example, a co-crystal with less than or about 0.01. 0.1, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, or 20 percent vacancies within the crystalline lattice are included in the present invention. The vacancies can be due to missing modafinil molecules or missing co-crystal former molecules from the crystalline lattice, or both.

It has surprisingly been found that when modafinil and a selected co-crystal former are allowed to form co-crystals, the resulting co-crystals give rise to improved properties of modafinil, as compared to modafinil in the free form, particularly with respect to: solubility, dissolution, bioavailability, stability, Cmax, Tmax, processability, longer lasting therapeutic plasma concentration, etc. For example, a co-crystal form of modafinil is particularly advantageous due to the low solubility of modafinil in water. Additionally, the co-crystal properties conferred upon modafinil are also useful because the bioavailability of modafinil can be improved and the plasma concentration and/or serum concentration of modafinil can be improved. This is particularly advantageous for orally-administrable formulations. Moreover, the dose response of modafinil can be improved, for example by increasing the maximum attainable response and/or increasing the potency of modafinil by increasing the biological activity per dosing equivalent.

Accordingly, in a first aspect, the present invention provides a pharmaceutical composition comprising a co-crystal of modafinil and a co-crystal former, such that the modafinil and the co-crystal former are capable of co-crystallizing from a solution phase

under crystallization conditions or from the solid-state, for example, through grinding or heating. In another aspect, the co-crystal former which has at least one functional group selected from the group consisting of ether, thioether, alcohol, thiol, aldehyde, ketone, thioketone, nitrate ester, phosphate ester, thiophosphate ester, ester, thioester, sulfate ester, carboxylic acid, phosphonic acid, phosphinic acid, sulfonic acid, amide, primary amine, secondary amine, ammonia, tertiary amine, sp2 amine, thiocyanate, cyanamide, oxime, nitrile, diazo, organohalide, nitro, S-heterocyclic ring, thiophene, N-heterocyclic ring, pyrrole, O-heterocyclic ring, furan, epoxide, peroxide, hydroxamic acid, imidazole, and pyridine, or a functional group in a Table herein, such that the modafinil and co-crystal former are capable of co-crystallizing from a solution phase under crystallization conditions.

In another embodiment, the use of an excess (more than 1 molar equivalent for a 1:1 co-crystal) of a co-crystal former can be used to drive the formation of stoichiometric co-crystals. For example, co-crystals with stoichiometries of 1:1, 2:1, or 1:2 can be produced by adding co-crystal former in an amount that is 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 50, 75, 100 times or more than the stoichiometric amount for a given co-crystal. Such an excessive use of a co-crystal former to form a co-crystal can be employed in solution or when grinding modafinil and a co-crystal former to cause co-crystal formation.

In another embodiment of the present invention, a modafinil co-crystal further comprises a co-crystal former which is hydrogen bonded via a preferred interaction between two or more functional groups. For example, modafinil and malonic acid co-crystallize through the interaction of a carboxylic acid functional group of the co-crystal former with sulfoxide and amide functional groups of modafinil.

In another embodiment of the present invention, the co-crystal comprises modafinil wherein the modafinil forms a dimeric primary amide structure via hydrogen bonds with an $R^2_2(8)$ motif. In such a structure, the NH_2 moiety can also participate in a hydrogen bond with a donor or an acceptor moiety from, for example, a co-crystal former or an additional (third) molecule, and the C=O moiety can participate in a hydrogen bond with a donor moiety from the co-crystal former or the additional molecule. In a further embodiment, the dimeric primary amide structure further comprises one, two, three, or four hydrogen bond donors. In a further embodiment, the

dimeric primary amide structure further comprises one or two hydrogen bond acceptors. In a further embodiment, the dimeric primary amide structure further comprises a combination of hydrogen bond donors and acceptors. For example, the dimeric primary amide structure can further comprise one hydrogen bond donor and one hydrogen bond acceptor, one hydrogen bond donor and two hydrogen bond acceptors, two hydrogen bond donors and one hydrogen bond acceptor, two hydrogen bond donors and two hydrogen bond acceptors, or three hydrogen bond donors and one hydrogen bond acceptor.

The co-crystals of the present invention are formed where modafinil and the co-crystal former are bonded together through hydrogen bonds. Other non-covalent interactions, including pi-stacking and van der Waals interactions, may also be present.

In one embodiment, the co-crystal former is selected from the co-crystal formers of Table I and Table II. In other embodiments, the co-crystal former of Table I is specified as a Class 1, Class 2, or Class 3 co-crystal former (see column labeled "class" Table I). Table I lists multiple pK_a values for co-crystal formers having multiple functionalities. It is readily apparent to one skilled in the art the particular functional group corresponding to a particular pK_a value.

In another embodiment the particular functional group of a co-crystal former interacting with modafinil is specified (see for example Table I, columns labeled "Functionality" and "Molecular Structure" and the column of Table II labeled "Co-Crystal Former Functional Group").

In another embodiment, the co-crystal comprises more than one co-crystal former. For example, two, three, four, five, or more co-crystal formers can be incorporated in a co-crystal with modafinil. Co-crystals which comprise two or more co-crystal formers and an API are bound together via hydrogen bonds. In one embodiment, incorporated co-crystal formers are hydrogen bonded to modafinil molecules. In another embodiment, co-crystal formers are hydrogen bonded to either the modafinil molecules or the incorporated co-crystal formers.

In each process according to the invention, there is a need to contact modafinil with the co-crystal former. This may involve grinding the two solids together or melting one or both components and allowing them to recrystallize. This may also involve either

solubilizing modafinil and adding the co-crystal former, or solubilizing the co-crystal former and adding modafinil. Crystallization conditions are applied to modafinil and the co-crystal former. This may entail altering a property of the solution, such as pH or temperature and may require concentration of the solute, usually by removal of the solvent, typically by drying the solution. Solvent removal results in the concentration of both modafinil and the co-crystal former increasing over time so as to facilitate crystallization. For example, evaporation, cooling, or the addition of an antisolvent may be used to crystallize co-crystals. In another embodiment, a slurry comprising modafinil and a co-crystal former is used to form co-crystals. Once the solid phase comprising any crystals is formed, this may be tested as described herein.

The co-crystals obtained as a result of such process steps may be readily incorporated into a pharmaceutical composition by conventional means. Pharmaceutical compositions in general are discussed in further detail below and may further comprise a pharmaceutically-acceptable diluent, excipient or carrier.

In a further aspect, the present invention provides a process for the production of a pharmaceutical composition, which process comprises:

(1) providing modafinil;

(2) providing a co-crystal former which has at least one functional group selected from the group consisting of ether, thioether, alcohol, thiol, aldehyde, ketone, thioketone, nitrate ester, phosphate ester, thiophosphate ester, ester, thioester, sulfate ester, carboxylic acid, phosphonic acid, phosphinic acid, sulfonic acid, amide, primary amine, secondary amine, ammonia, tertiary amine, sp2 amine, thiocyanate, cyanamide, oxime, nitrile, diazo, organohalide, nitro, S-heterocyclic ring, thiophene, N-heterocyclic ring, pyrrole, O-heterocyclic ring, furan, epoxide, peroxide, hydroxamic acid, imidazole, and pyridine or of Table I, II, or III;

(3) grinding, heating, co-subliming, co-melting, or contacting in solution the modafinil with the co-crystal former under crystallization conditions;

(4) isolating co-crystals formed thereby; and

(5) incorporating the co-crystals into a pharmaceutical composition.

In a still further aspect the present invention provides a process for the production of a pharmaceutical composition, which comprises:

(1) grinding, heating, co-subliming, co-melting, or contacting in solution modafinil with a co-crystal former, under crystallization conditions, so as to form a solid phase;

(2) isolating co-crystals comprising the modafinil and the co-crystal former; and

(3) incorporating the co-crystals into a pharmaceutical composition.

In another embodiment, a process for the formation of co-crystals includes a meta-stable form of modafinil, the co-crystal former, or both. A meta-stable form can be for example, but not limited to, a polymorph, solvate, or hydrate of modafinil or the co-crystal former. While not bound by theory, the incorporation of a meta-stable form may facilitate co-crystal formation via increasing the thermodynamic driving force.

Assaying the solid phase for the presence of co-crystals of modafinil and the co-crystal former may be carried out by conventional methods known in the art. For example, it is convenient and routine to use powder X-ray diffraction techniques to assess the presence of co-crystals. This may be affected by comparing the diffractograms of modafinil, the crystal former and putative co-crystals in order to establish whether or not true co-crystals had been formed. Other techniques, used in an analogous fashion, include differential scanning calorimetry (DSC), thermogravimetric analysis (TGA) and Raman spectroscopy. Single crystal X-ray diffraction is especially useful in identifying co-crystal structures.

In a further aspect, the present invention therefore provides a process of screening for co-crystal compounds, which comprises:

(1) providing (*i*) modafinil and (*ii*) a co-crystal former; and

(2) screening for co-crystals of the modafinil with the co-crystal former by subjecting each combination of modafinil and co-crystal former to a procedure comprising:

(a) grinding, heating, co-subliming, co-melting, or contacting in solution the modafinil with the co-crystal former under crystallization conditions so as to form a solid phase; and

(b) isolating co-crystals comprising the modafinil and the co-crystal former.

An alternative embodiment is drawn to a process of screening for co-crystal compounds, which comprises:

(1) providing (*i*) modafinil and (*ii*) a plurality of different co-crystal formers; and

(2) screening for co-crystals of the modafinil with the co-crystal formers by subjecting each combination of the modafinil and the co-crystal formers to a procedure comprising:

(a) grinding, heating, co-subliming, co-melting, or contacting in solution the modafinil with each co-crystal former under crystallization conditions so as to form a solid phase; and

(b) isolating co-crystals comprising the modafinil and the co-crystal former.

The present invention includes several co-crystals comprising modafinil and a carboxylic acid co-crystal former. Some examples include modafinil co-crystals comprising malonic acid, tartaric acid (L- and DL-), succinic acid, citric acid, fumaric acid, gentisic acid, oxalic acid, and 1-hydroxy-2-naphthoic acid. These examples represent mono-, di- and tri-carboxylic acid co-crystal formers. Other acids, including carboxylic acids, may be used as co-crystal formers with modafinil including, but not limited to, palmitic acid, lauric acid, orotic acid, and adipic acid etc. These co-crystal formers may comprise one, two, three, or more carboxylic acid functional groups. Co-crystal formers can also include non-carboxylic acid molecules such as, but not limited to, urea, saccharin, and caffeine.

In another embodiment, a co-crystal comprises modafinil and a carboxylic acid as a co-crystal former. In another embodiment, the carboxylic acid co-crystal former has one, two, three, or more carboxylic acid functional groups.

Several co-crystals may exhibit one or more particular interactions between modafinil and a carboxylic acid co-crystal former. For example, a carboxylic acid functional group can interact with the primary amide and/or the S=O functional group of modafinil via a hydrogen bond. In another embodiment, a carboxylic acid functional group from the co-crystal former interacts with the primary amide functional group or the S=O functional group of modafinil. In another embodiment, a carboxylic acid functional group from the co-crystal former interacts with the periphery of the amide dimer of modafinil. In another embodiment, a carboxylic acid functional group from the co-crystal former interacts with the amide dimer and the S=O functional group of modafinil. In another embodiment, a carboxylic acid functional group from the co-crystal former interacts with two amide dimers of modafinil.

Modafinil and some co-crystal formers of the present invention have one or more chiral centers and may exist in a variety of stereoisomeric configurations. As a consequence of these chiral centers, modafinil and several co-crystal formers of the present invention occur as racemates, mixtures of enantiomers and as individual enantiomers, as well as diastereomers and mixtures of diastereomers. All such racemates, enantiomers, and diastereomers are within the scope of the present invention including, for example, *cis*- and *trans*-isomers, R- and S-enantiomers, and (D)- and (L)-isomers. Co-crystals of the present invention can include isomeric forms of either modafinil or the co-crystal former or both. Isomeric forms of modafinil and co-crystal formers include, but are not limited to, stereoisomers such as enantiomers and diastereomers. In one embodiment, a co-crystal can comprise racemic modafinil and/or a co-crystal former. In another embodiment, a co-crystal can comprise enantiomerically pure modafinil and/or a co-crystal former. In another embodiment, a co-crystal can comprise modafinil or a co-crystal former with an enantiomeric excess of about 50 percent, 55 percent, 60 percent, 65 percent, 70 percent, 75 percent, 80 percent, 85 percent, 90 percent, 95 percent, 96 percent, 97 percent, 98 percent, 99 percent, greater than 99 percent, or any intermediate value. Several non-limiting examples of stereoisomeric co-crystal formers include tartaric acid and malic acid.

Co-crystals comprising enantiomerically pure components (e.g., modafinil or co-crystal former) can give rise to chemical and/or physical properties which are modulated

with respect to those of the corresponding co-crystal comprising a racemic component. For example, the modafinil:malonic acid co-crystal from Example 1 comprises racemic modafinil. Enantiomerically pure R-(-)-modafinil:malonic acid is included in the scope of the invention. Likewise, enantiomerically pure S-(+)-modafinil:malonic acid can is included in the scope of the invention. A co-crystal comprising an enantiomerically pure component can give rise to a modulation of, for example, activity, bioavailability, or solubility, with respect to the corresponding co-crystal comprising a racemic component. As an example, the co-crystal R-(-)-modafinil:malonic acid can have modulated properties as compared to the racemic modafinil:malonic acid co-crystal.

As used herein and unless otherwise specified, the term "racemic co-crystal" refers to a co-crystal which is comprised of an equimolar mixture of two enantiomers of modafinil, the co-crystal former, or both. For example, a co-crystal comprising modafinil and a non-stereoisomeric co-crystal former is a "racemic co-crystal" only when there is present an equimolar mixture of the modafinil enantiomers. Similarly, a co-crystal comprising modafinil and a stereoisomeric co-crystal former is a "racemic co-crystal" only when there is present an equimolar mixture of the modafinil enantiomers and of the co-crystal former enantiomers.

As used herein and unless otherwise specified, the term "enantiomerically pure co-crystal" refers to a co-crystal which is comprised of modafinil and a stereoisomeric or non-stereoisomeric co-crystal former where the enantiomeric excess of the stereoisomeric species is greater than or equal to about 90 percent *ee* (enantiomeric excess).

In another embodiment, the present invention includes a pharmaceutical composition comprising a co-crystal with enantiomerically pure modafinil and/or co-crystal former wherein the bioavailability is modulated with respect to the racemic co-crystal. In another embodiment, the present invention includes a pharmaceutical composition comprising a co-crystal with enantiomerically pure modafinil and/or co-crystal former wherein the activity is modulated with respect to the racemic co-crystal. In another embodiment, the present invention includes a pharmaceutical composition comprising a co-crystal with enantiomerically pure modafinil and/or co-crystal former wherein the solubility is modulated with respect to the racemic co-crystal.

As used herein and unless otherwise specified, the term "enantiomerically pure"

includes a composition which is substantially enantiomerically pure and includes, for example, a composition with greater than or equal to about 90, 91, 92, 93, 94, 95, 96, 97, 98, or 99 percent enantiomeric excess.

As used herein, the term "modafinil" includes both the racemate and single enantiomers, but may be specifically set forth as the racemate, R-isomer, S-isomer, or any mixture of both R- and S-isomers.

In another embodiment, a pharmaceutical composition can be formulated to contain modafinil in co-crystal form as micronized or nano-sized particles. More specifically, another embodiment couples the processing of pure modafinil to a co-crystal form with the process of making a controlled particle size for manipulation into a pharmaceutical dosage form. This embodiment combines two processing steps into a single step via techniques such as, but not limited to, grinding, alloying, or sintering (i.e., heating a powder mix). The coupling of these processes overcomes a serious limitation of having to isolate and store the bulk drug that is required for a formulation, which in some cases can be difficult to isolate (e.g., amorphous, chemically or physically unstable).

<u>Solubility Modulation</u>

In a further aspect, the present invention provides a process for modulating the solubility of modafinil, which process comprises:

(1) grinding, heating, co-subliming, co-melting, or contacting in solution modafinil with a co-crystal former under crystallization conditions, so as to form a co-crystal of modafinil and the co-crystal former; and

(2) isolating co-crystals comprising the modafinil and the co-crystal former.

In one embodiment, the solubility of modafinil is modulated such that the aqueous solubility is increased. Solubility of modafinil may be measured by any conventional means such as chromatography (e.g., HPLC) or spectroscopic determination of the amount of modafinil in a saturated solution, such as UV-spectroscopy, IR-spectroscopy, Raman spectroscopy, quantitative mass spectroscopy, or gas chromatography.

In another embodiment, the co-crystals, solvates, and polymorphs of the present invention can be compared with free form modafinil as found in PROVIGIL® (Cephalon, Inc.). (See US Reissued Patent No. RE37,516) For example, the bioavailability of an embodiment of the present invention can be compared with that of PROVIGIL. As embodiments of the present invention, solubility can be increased 2, 3, 4, 5, 7, 10, 15, 20, 25, 50, 75, or 100 times by making a co-crystal of the reference form (e.g., crystalline or amorphous free form, hydrate or solvate). Further aqueous solubility can be measured in simulated gastric fluid (SGF) or simulated intestinal fluid (SIF) rather than water. SGF (non-diluted) of the present invention is made by combining 1 g/L Triton X-100 and 2 g/L NaCl in water and adjusting the pH with 20 mM HCl to obtain a solution with a final pH=1.7 (SIF is 0.68% monobasic potassium phosphate, 1% pancreatin, and sodium hydroxide where the pH of the final solution is 7.5). The pH of the solvent used may also be specified as 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, 10, 10.5, 11, 11.5, or 12, or any pH in between successive values.

Examples of embodiments includes: co-crystal compositions with an aqueous solubility, at 37 degrees C and a pH of 7.0, that is increased at least 5 fold over the reference form, co-crystal compositions with a solubility in SGF that is increased at least 5 fold over the reference form, co-crystal compositions with a solubility in SIF that is increased at least 5 fold over the reference form.

Dissolution Modulation

In another aspect of the present invention, the dissolution profile of modafinil is modulated whereby the aqueous dissolution rate or the dissolution rate in simulated gastric fluid or in simulated intestinal fluid, or in a solvent or plurality of solvents is increased. Dissolution rate is the rate at which API solids dissolve in a dissolution medium. For APIs whose absorption rates are faster than the dissolution rates (e.g., steroids), the rate-limiting step in the absorption process is often the dissolution rate. Because of a limited residence time at the absorption site, APIs that are not dissolved before they are removed from intestinal absorption site are considered useless. Therefore, the rate of dissolution has a major impact on the performance of APIs that are poorly

soluble. Because of this factor, the dissolution rate of APIs in solid dosage forms is an important, routine, quality control parameter used in the API manufacturing process.

Dissolution rate = K S (C_s-C)

where K is dissolution rate constant, S is the surface area, C_s is the apparent solubility, and C is the concentration of API in the dissolution medium.

For rapid API absorption, C_s-C is approximately equal to C_s

The dissolution rate of modafinil may be measured by conventional means known in the art.

The increase in the dissolution rate of a co-crystal, as compared to the reference form (e.g., free form), may be specified, such as by 10, 20, 30, 40, 50, 60, 70, 80, 90, or 100%, or by 2, 3, 4, 5 ,6, 7, 8, 9, 10, 15, 20, 25, 30, 40, 50, 75, 100, 125, 150, 175, 200, 250, 300, 350, 400, 500, 1000, 10,000, or 100,000 fold greater than the reference form (e.g., free form) in the same solution. Conditions under which the dissolution rate is measured are the same as discussed above. The increase in dissolution may be further specified by the time the composition remains supersaturated before reaching equilibrium solubility.

Examples of above embodiments include: co-crystal compositions with a dissolution rate in aqueous solution, at 37 degrees C and a pH of 7.0, that is increased at least 5 fold over the reference form, co-crystal compositions with a dissolution rate in SGF that is increased at least 5 fold over the reference form, co-crystal compositions with a dissolution rate in SIF that is increased at least 5 fold over the reference form.

Bioavailability Modulation

The methods of the present invention are used to make a pharmaceutical modafinil formulation with greater solubility, dissolution, and bioavailability. Bioavailability can be improved via an increase in AUC, reduced time to T_{max}, (the time to reach peak blood serum levels), or increased C_{max}. The present invention can result in higher plasma concentrations of modafinil when compared to the free form (reference form).

AUC is the area under the plot of plasma concentration of API (not logarithm of the concentration) against time after API administration. The area is conveniently determined by the "trapezoidal rule": The data points are connected by straight line segments, perpendiculars are erected from the abscissa to each data point, and the sum of the areas of the triangles and trapezoids so constructed is computed. When the last measured concentration (C_n, at time t_n) is not zero, the AUC from t_n to infinite time is estimated by C_n/k_{el}.

The AUC is of particular use in estimating bioavailability of APIs, and in estimating total clearance of APIs (Cl_T). Following single intravenous doses, AUC = D/Cl_T, for single compartment systems obeying first-order elimination kinetics, where D is the dose; alternatively, AUC = C_0/k_{el}, where k_{el} is the API elimination rate constant. With routes other than the intravenous, AUC = $F \cdot D/Cl_T$, where F is the absolute bioavailability of the API.

Thus, in a further aspect, the present invention provides a process for modulating the bioavailability of modafinil when administered in its normal and effective dose range as a co-crystal, whereby the AUC is increased or the time to T_{max} is increased, as compared to a reference form, which process comprises:

(1) grinding, heating, co-subliming, co-melting, or contacting in solution modafinil with a co-crystal former under crystallization conditions, so as to form a co-crystal of the modafinil and the co-crystal former; and

(2) isolating co-crystals comprising the modafinil and the co-crystal former.

Examples of the above embodiments include: co-crystal compositions with a time to T_{max} that is increased by at least 5% as compared to the reference form, co-crystal compositions with a time to T_{max} that is increased by at least 10% over the reference form, co-crystal compositions with a time to T_{max} that is increased by at least 15% over the reference form, co-crystal compositions with a time to T_{max} that is increased by at least 20% over the reference form, co-crystal compositions with a T_{max} that is increased by at least 25% over the reference form, co-crystal compositions with a T_{max} that is increased by at least 30% over the reference form, co-crystal compositions with a T_{max} that is increased by at least 35% over the reference form, co-crystal compositions with a T_{max} that is increased by at least 40% over the reference form, co-crystal compositions

with an AUC that is increased by at least 5% over the reference form, co-crystal compositions with an AUC that is increased by at least 10% over the reference form, co-crystal compositions with an AUC that is increased by at least 15% over the reference form, co-crystal compositions with an AUC that is increased by at least 20% over the reference form, co-crystal compositions with an AUC that is increased by at least 25% over the reference form, co-crystal compositions with an AUC that is increased by at least 30% over the reference form, co-crystal compositions with an AUC that is increased by at least 35% over the reference form, co-crystal compositions with an AUC that is increased by at least 40% over the reference form. Other examples include wherein the reference form is crystalline, wherein the reference form is amorphous, or wherein the reference form is an anhydrous crystal of modafinil.

Dose Response Modulation

In a further aspect the present invention provides a process for improving the dose response of modafinil, which process comprises:

(1) grinding, heating, co-subliming, co-melting, or contacting in solution modafinil with a co-crystal former under crystallization conditions, so as to form a co-crystal of the modafinil and the co-crystal former; and

(2) isolating co-crystals comprising the modafinil and the co-crystal former.

Dose response is the quantitative relationship between the magnitude of response and the dose inducing the response and may be measured by conventional means known in the art. The curve relating effect (as the dependent variable) to dose (as the independent variable) for an API-cell system is the "dose-response curve". Typically, the dose-response curve is the measured response to an API plotted against the dose of the API (mg/kg) given. The dose response curve can also be a curve of AUC against the dose of the API given.

In an embodiment of the present invention, a co-crystal of the present invention has an increased dose response curve or a more linear dose response curve than the corresponding reference compound.

Increased Stability

In a still further aspect the present invention provides a process for improving the stability of modafinil (as compared to a reference form such as its free form), which process comprises:

(1) grinding, heating, co-subliming, co-melting, or contacting in solution modafinil with a co-crystal former under crystallization conditions, so as to form a co-crystal of the modafinil and the co-crystal former; and

(2) isolating co-crystals comprising the modafinil and the co-crystal former.

In a preferred embodiment, the compositions of the present invention, including modafinil co-crystals, solvates, and formulations comprising modafinil, are suitably stable for pharmaceutical use. Preferably, modafinil or formulations thereof, of the present invention, are stable such that when stored at 30 degrees C for 2 years, less than 0.2 % of any one degradant is formed. The term degradant refers herein to product(s) of a single type of chemical reaction. For example, if a hydrolysis event occurs that cleaves a molecule into two products, for the purpose of the present invention, it would be considered a single degradant. More preferably, when stored at 40 degrees C for 2 years, less than 0.2 % of any one degradant is formed. Alternatively, when stored at 30 degrees C for 3 months, less than 0.2 % or 0.15 %, or 0.1 % of any one degradant is formed, or when stored at 40 degrees C for 3 months, less than 0.2 % or 0.15 %, or 0.1 % of any one degradant is formed. Further alternatively, when stored at 60 degrees C for 4 weeks, less than 0.2 % or 0.15 %, or 0.1 % of any one degradant is formed. The relative humidity (RH) may be specified as ambient RH, 75 % RH, or as any single integer between 1 to 99 % RH. In another embodiment, a single dose of the present invention comprises less than 0.5 %, 0.2 %, or 0.1 % degradants upon administration to a subject.

Morphology Modulation

In a still further aspect the present invention provides a process for modifying the morphology of modafinil, which process comprises:

(1) grinding, heating, co-subliming, co-melting, or contacting in solution modafinil with a co-crystal former under crystallization conditions, so as to form a co-crystal of the modafinil and the co-crystal former; and

(2) isolating co-crystals comprising the modafinil and the co-crystal former.

In an embodiment the co-crystal comprises or consists of modafinil and a co-crystal former wherein the interaction between the two, e.g., H-bonding, occurs between the amino group of modafinil and a co-crystal former with a corresponding interacting group of Table III. In a further embodiment, the co-crystal comprises modafinil and a co-crystal former of Table I or II. In an aspect of the invention, only co-crystals having an H-bond acceptor on the first molecule and an H-bond donor on the second molecule, where the first and second molecules are either co-crystal former and modafinil respectively, or modafinil and co-crystal former respectively, are included in the present invention.

A co-crystal can comprise more than two chemical entities within its co-crystalline structure. For example, a co-crystal can further comprise a solvent molecule, a water molecule, a salt, etc. In addition, a co-crystal can comprise an API and two or more co-crystal formers, a co-crystal former and two or more APIs, two or more APIs, or two or more co-crystal formers.

As defined herein, a ternary co-crystal is a co-crystal which comprises three distinct chemical entities in a stoichiometric ratio, where each is a solid at room temperature (with the exception that the API may be a liquid at room temperature). Specifically, a ternary co-crystal comprises three distinct chemical entities such as API:co-crystal former(1):co-crystal former(2), where the ratio of components can be, for example, but not limited to, 1:1:1, 2:1:1, 2:1:2, 2:1:0.5, 2:2:1, etc. Ternary co-crystals can also comprise other combinations of components such as, but not limited to, API(1):API(2):co-crystal former, API(1):API(2):API(3), and co-crystal former(1):co-crystal former(2):co-crystal former(3).

Pharmaceutically acceptable co-crystals can be administered by controlled- or delayed-release means. Controlled-release pharmaceutical products have a common goal of improving drug therapy over that achieved by their non-controlled release

counterparts. Ideally, the use of an optimally designed controlled-release preparation in medical treatment is characterized by a minimum of drug substance being employed to cure or control the condition in a minimum amount of time. Advantages of controlled-release formulations include: 1) extended activity of the drug; 2) reduced dosage frequency; 3) increased patient compliance; 4) usage of less total drug; 5) reduction in local or systemic side effects; 6) minimization of drug accumulation; 7) reduction in blood level fluctuations; 8) improvement in efficacy of treatment; 9) reduction of potentiation or loss of drug activity; and 10) improvement in speed of control of diseases or conditions. (Kim, Cherng-ju, Controlled Release Dosage Form Design, 2 Technomic Publishing, Lancaster, Pa.: 2000).

Conventional dosage forms generally provide rapid or immediate drug release from the formulation. Depending on the pharmacology and pharmacokinetics of the drug, use of conventional dosage forms can lead to wide fluctuations in the concentrations of the drug in a patient's blood and other tissues. These fluctuations can impact a number of parameters, such as dose frequency, onset of action, duration of efficacy, maintenance of therapeutic blood levels, toxicity, side effects, and the like. Advantageously, controlled-release formulations can be used to control a drug's onset of action, duration of action, plasma levels within the therapeutic window, and peak blood levels. In particular, controlled- or extended-release dosage forms or formulations can be used to ensure that the maximum effectiveness of a drug is achieved while minimizing potential adverse effects and safety concerns, which can occur both from under dosing a drug (i.e., going below the minimum therapeutic levels) as well as exceeding the toxicity level for the drug.

Most controlled-release formulations are designed to initially release an amount of drug (active ingredient) that promptly produces the desired therapeutic effect, and gradually and continually release other amounts of drug to maintain this level of therapeutic or prophylactic effect over an extended period of time. In order to maintain this constant level of drug in the body, the drug must be released from the dosage form at a rate that will replace the amount of drug being metabolized and excreted from the body. Controlled-release of an active ingredient can be stimulated by various conditions

including, but not limited to, pH, ionic strength, osmotic pressure, temperature, enzymes, water, and other physiological conditions or compounds.

A variety of known controlled- or extended-release dosage forms, formulations, and devices can be adapted for use with the co-crystals and compositions of the invention. Examples include, but are not limited to, those described in U.S. Pat. Nos.: 3,845,770; 3,916,899; 3,536,809; 3,598,123; 4,008,719; 5,674,533; 5,059,595; 5,591,767; 5,120,548; 5,073,543; 5,639,476; 5,354,556; 5,733,566; and 6,365,185 B1; each of which is incorporated herein by reference. These dosage forms can be used to provide slow or controlled-release of one or more active ingredients using, for example, hydroxypropylmethyl cellulose, other polymer matrices, gels, permeable membranes, osmotic systems (such as OROS® (Alza Corporation, Mountain View, Calif. USA)), multilayer coatings, microparticles, liposomes, or microspheres or a combination thereof to provide the desired release profile in varying proportions. Additionally, ion exchange materials can be used to prepare immobilized, adsorbed co-crystals and thus effect controlled delivery of the drug. Examples of specific anion exchangers include, but are not limited to, Duolite® A568 and Duolite® AP143 (Rohm & Haas, Spring House, PA. USA).

One embodiment of the invention encompasses a unit dosage form which comprises a pharmaceutically acceptable co-crystal, or a solvate, hydrate, dehydrate, anhydrous, or amorphous form thereof, and one or more pharmaceutically acceptable excipients or diluents, wherein the pharmaceutical composition or dosage form is formulated for controlled-release. Specific dosage forms utilize an osmotic drug delivery system.

A particular and well-known osmotic drug delivery system is referred to as OROS® (Alza Corporation, Mountain View, Calif. USA). This technology can readily be adapted for the delivery of compounds and compositions of the invention. Various aspects of the technology are disclosed in U.S. Pat. Nos. 6,375,978 B1; 6,368,626 B1; 6,342,249 B1; 6,333,050 B2; 6,287,295 B1; 6,283,953 B1; 6,270,787 B1; 6,245,357 B1; and 6,132,420; each of which is incorporated herein by reference. Specific adaptations of OROS® that can be used to administer compounds and compositions of the invention include, but are not limited to, the OROS® Push-Pull™, Delayed Push-Pull™, Multi-

Layer Push-Pull™, and Push-Stick™ Systems, all of which are well known. See, e.g., http://www.alza.com. Additional OROS® systems that can be used for the controlled oral delivery of compounds and compositions of the invention include OROS®-CT and L-OROS®. Id.; see also, Delivery Times, vol. II, issue II (Alza Corporation).

Conventional OROS® oral dosage forms are made by compressing a drug powder (e.g. co-crystal) into a hard tablet, coating the tablet with cellulose derivatives to form a semi-permeable membrane, and then drilling an orifice in the coating (e.g., with a laser). Kim, Cherng-ju, Controlled Release Dosage Form Design, 231-238 (Technomic Publishing, Lancaster, Pa.: 2000). The advantage of such dosage forms is that the delivery rate of the drug is not influenced by physiological or experimental conditions. Even a drug with a pH-dependent solubility can be delivered at a constant rate regardless of the pH of the delivery medium. But because these advantages are provided by a build-up of osmotic pressure within the dosage form after administration, conventional OROS® drug delivery systems cannot be used to effectively deliver drugs with low water solubility. Id. at 234. Because co-crystals of this invention can be far more soluble in water than modafinil itself, they are well suited for osmotic-based delivery to patients. This invention does, however, encompass the incorporation of conventional crystalline modafinil (e.g. pure modafinil without co-crystal former), and isomers and isomeric mixtures thereof, into OROS® dosage forms.

A specific dosage form of the invention comprises: a wall defining a cavity, the wall having an exit orifice formed or formable therein and at least a portion of the wall being semipermeable; an expandable layer located within the cavity remote from the exit orifice and in fluid communication with the semipermeable portion of the wall; a dry or substantially dry state drug layer located within the cavity adjacent to the exit orifice and in direct or indirect contacting relationship with the expandable layer; and a flow-promoting layer interposed between the inner surface of the wall and at least the external surface of the drug layer located within the cavity, wherein the drug layer comprises a co-crystal, or a solvate, hydrate, dehydrate, anhydrous, or amorphous form thereof. See U.S. Pat. No. 6,368,626, the entirety of which is incorporated herein by reference.

Another specific dosage form of the invention comprises: a wall defining a cavity, the wall having an exit orifice formed or formable therein and at least a portion of the

wall being semipermeable; an expandable layer located within the cavity remote from the exit orifice and in fluid communication with the semipermeable portion of the wall; a drug layer located within the cavity adjacent the exit orifice and in direct or indirect contacting relationship with the expandable layer; the drug layer comprising a liquid, active agent formulation absorbed in porous particles, the porous particles being adapted to resist compaction forces sufficient to form a compacted drug layer without significant exudation of the liquid, active agent formulation, the dosage form optionally having a placebo layer between the exit orifice and the drug layer, wherein the active agent formulation comprises a co-crystal, or a solvate, hydrate, dehydrate, anhydrous, or amorphous form thereof. See U.S. Pat. No. 6,342,249, the entirety of which is incorporated herein by reference.

In another embodiment, a pharmaceutical composition comprises a mixture of a novel form of modafinil of the present invention (e.g., a co-crystal) and the free form of modafinil. This embodiment can be used, for example, as a controlled-, sustained-, or extended-release dosage form. In another embodiment, an extended-release dosage form comprises free form modafinil and a co-crystal or a solvate of the present invention. Such an extended-release dosage form contains modafinil in a form (e.g. modafinil:malonic acid co-crystal) which has a greater bioavailability than that of free form modafinil. In addition, the C_{max} of such a form can be greater than that of free form modafinil, facilitating a therapeutic effect with longer duration than free form modafinil alone.

Excipients employed in pharmaceutical compositions of the present invention can be solids, semi-solids, liquids or combinations thereof. Preferably, excipients are solids. Compositions of the invention containing excipients can be prepared by known technique of pharmacy that comprises admixing an excipient with an API or therapeutic agent. A pharmaceutical composition of the invention contains a desired amount of API per dose unit and, if intended for oral administration, can be in the form, for example, of a tablet, a caplet, a pill, a hard or soft capsule, a lozenge, a cachet, a dispensable powder, granules, a suspension, an elixir, a dispersion, a liquid, or any other form reasonably adapted for such administration. If intended for parenteral administration, it can be in the form, for example, of a suspension or transdermal patch. If intended for rectal administration, it

can be in the form, for example, of a suppository. Presently preferred are oral dosage forms that are discrete dose units each containing a predetermined amount of the API, such as tablets or capsules.

Non-limiting examples follow of excipients that can be used to prepare pharmaceutical compositions of the invention.

Pharmaceutical compositions of the invention optionally comprise one or more pharmaceutically acceptable carriers or diluents as excipients. Suitable carriers or diluents illustratively include, but are not limited to, either individually or in combination, lactose, including anhydrous lactose and lactose monohydrate; starches, including directly compressible starch and hydrolyzed starches (e.g., Celutab™ and Emdex™); mannitol; sorbitol; xylitol; dextrose (e.g., Cerelose™ 2000) and dextrose monohydrate; dibasic calcium phosphate dihydrate; sucrose-based diluents; confectioner's sugar; monobasic calcium sulfate monohydrate; calcium sulfate dihydrate; granular calcium lactate trihydrate; dextrates; inositol; hydrolyzed cereal solids; amylose; celluloses including microcrystalline cellulose, food grade sources of alpha- and amorphous cellulose (e.g., RexcelJ), powdered cellulose, hydroxypropylcellulose (HPC) and hydroxypropylmethylcellulose (HPMC); calcium carbonate; glycine; bentonite; block co-polymers; polyvinylpyrrolidone; and the like. Such carriers or diluents, if present, constitute in total about 5% to about 99%, preferably about 10% to about 85%, and more preferably about 20% to about 80%, of the total weight of the composition. The carrier, carriers, diluent, or diluents selected preferably exhibit suitable flow properties and, where tablets are desired, compressibility.

Lactose, mannitol, dibasic sodium phosphate, and microcrystalline cellulose (particularly Avicel PH microcrystalline cellulose such as Avicel PH 101), either individually or in combination, are preferred diluents. These diluents are chemically compatible with APIs. The use of extragranular microcrystalline cellulose (that is, microcrystalline cellulose added to a granulated composition) can be used to improve hardness (for tablets) and/or disintegration time. Lactose, especially lactose monohydrate, is particularly preferred. Lactose typically provides compositions having suitable release rates of APIs, stability, pre-compression flowability, and/or drying properties at a relatively low diluent cost. It provides a high density substrate that aids

densification during granulation (where wet granulation is employed) and therefore improves blend flow properties and tablet properties.

Pharmaceutical compositions of the invention optionally comprise one or more pharmaceutically acceptable disintegrants as excipients, particularly for tablet formulations. Suitable disintegrants include, but are not limited to, either individually or in combination, starches, including sodium starch glycolate (e.g., Explotab™ of PenWest) and pregelatinized corn starches (e.g., National™ 1551 of National Starch and Chemical Company, National™ 1550, and Colocorn™ 1500), clays (e.g., Veegum™ HV of R.T. Vanderbilt), celluloses such as purified cellulose, microcrystalline cellulose, methylcellulose, carboxymethylcellulose and sodium carboxymethylcellulose, croscarmellose sodium (e.g., Ac-Di-Sol™ of FMC), alginates, crospovidone, and gums such as agar, guar, locust bean, karaya, pectin and tragacanth gums.

Disintegrants may be added at any suitable step during the preparation of the composition, particularly prior to granulation or during a lubrication step prior to compression. Such disintegrants, if present, constitute in total about 0.2% to about 30%, preferably about 0.2% to about 10%, and more preferably about 0.2% to about 5%, of the total weight of the composition.

Croscarmellose sodium is a preferred disintegrant for tablet or capsule disintegration, and, if present, preferably constitutes about 0.2% to about 10%, more preferably about 0.2% to about 7%, and still more preferably about 0.2% to about 5%, of the total weight of the composition. Croscarmellose sodium confers superior intragranular disintegration capabilities to granulated pharmaceutical compositions of the present invention.

Pharmaceutical compositions of the invention optionally comprise one or more pharmaceutically acceptable binding agents or adhesives as excipients, particularly for tablet formulations. Such binding agents and adhesives preferably impart sufficient cohesion to the powder being tableted to allow for normal processing operations such as sizing, lubrication, compression and packaging, but still allow the tablet to disintegrate and the composition to be absorbed upon ingestion. Such binding agents may also prevent or inhibit crystallization or recrystallization of an API of the present invention once the salt has been dissolved in a solution. Suitable binding agents and adhesives

include, but are not limited to, either individually or in combination, acacia; tragacanth; sucrose; gelatin; glucose; starches such as, but not limited to, pregelatinized starches (e.g., National™ 1511 and National™ 1500); celluloses such as, but not limited to, methylcellulose and carmellose sodium (e.g., Tylose™); alginic acid and salts of alginic acid; magnesium aluminum silicate; PEG; guar gum; polysaccharide acids; bentonites; povidone, for example povidone K-15, K-30 and K-29/32; polymethacrylates; HPMC; hydroxypropylcellulose (e.g., Klucel™ of Aqualon); and ethylcellulose (e.g., Ethocel™ of the Dow Chemical Company). Such binding agents and/or adhesives, if present, constitute in total about 0.5% to about 25%, preferably about 0.75% to about 15%, and more preferably about 1% to about 10%, of the total weight of the pharmaceutical composition.

Many of the binding agents are polymers comprising amide, ester, ether, alcohol or ketone groups and, as such, are preferably included in pharmaceutical compositions of the present invention. Polyvinylpyrrolidones such as povidone K-30 are especially preferred. Polymeric binding agents can have varying molecular weight, degrees of crosslinking, and grades of polymer. Polymeric binding agents can also be copolymers, such as block co-polymers that contain mixtures of ethylene oxide and propylene oxide units. Variation in these units' ratios in a given polymer affects properties and performance. Examples of block co-polymers with varying compositions of block units are Poloxamer 188 and Poloxamer 237 (BASF Corporation).

Pharmaceutical compositions of the invention optionally comprise one or more pharmaceutically acceptable wetting agents as excipients. Such wetting agents are preferably selected to maintain the API in close association with water, a condition that is believed to improve bioavailability of the composition.

Non-limiting examples of surfactants that can be used as wetting agents in pharmaceutical compositions of the invention include quaternary ammonium compounds, for example benzalkonium chloride, benzethonium chloride and cetylpyridinium chloride, dioctyl sodium sulfosuccinate, polyoxyethylene alkylphenyl ethers, for example nonoxynol 9, nonoxynol 10, and octoxynol 9, poloxamers (polyoxyethylene and polyoxypropylene block copolymers), polyoxyethylene fatty acid glycerides and oils, for example polyoxyethylene (8) caprylic/capric mono- and diglycerides (e.g., Labrasol™ of

Gattefosse), polyoxyethylene (35) castor oil and polyoxyethylene (40) hydrogenated castor oil; polyoxyethylene alkyl ethers, for example polyoxyethylene (20) cetostearyl ether, polyoxyethylene fatty acid esters, for example polyoxyethylene (40) stearate, polyoxyethylene sorbitan esters, for example polysorbate 20 and polysorbate 80 (e.g., Tween™ 80 of ICI), propylene glycol fatty acid esters, for example propylene glycol laurate (e.g., Lauroglycol™ of Gattefosse), sodium lauryl sulfate, fatty acids and salts thereof, for example oleic acid, sodium oleate and triethanolamine oleate, glyceryl fatty acid esters, for example glyceryl monostearate, sorbitan esters, for example sorbitan monolaurate, sorbitan monooleate, sorbitan monopalmitate and sorbitan monostearate, tyloxapol, and mixtures thereof. Such wetting agents, if present, constitute in total about 0.25% to about 15%, preferably about 0.4% to about 10%, and more preferably about 0.5% to about 5%, of the total weight of the pharmaceutical composition.

Wetting agents that are anionic surfactants are preferred. Sodium lauryl sulfate is a particularly preferred wetting agent. Sodium lauryl sulfate, if present, constitutes about 0.25% to about 7%, more preferably about 0.4% to about 4%, and still more preferably about 0.5% to about 2%, of the total weight of the pharmaceutical composition.

Pharmaceutical compositions of the invention optionally comprise one or more pharmaceutically acceptable lubricants (including anti-adherents and/or glidants) as excipients. Suitable lubricants include, but are not limited to, either individually or in combination, glyceryl behapate (e.g., Compritol™ 888 of Gattefosse); stearic acid and salts thereof, including magnesium, calcium and sodium stearates; hydrogenated vegetable oils (e.g., Sterotex™ of Abitec); colloidal silica; talc; waxes; boric acid; sodium benzoate; sodium acetate; sodium fumarate; sodium chloride; DL-leucine; PEG (e.g., Carbowax™ 4000 and Carbowax™ 6000 of the Dow Chemical Company); sodium oleate; sodium lauryl sulfate; and magnesium lauryl sulfate. Such lubricants, if present, constitute in total about 0. 1% to about 10%, preferably about 0.2% to about 8%, and more preferably about 0.25% to about 5%, of the total weight of the pharmaceutical composition.

Magnesium stearate is a preferred lubricant used, for example, to reduce friction between the equipment and granulated mixture during compression of tablet formulations.

Suitable anti-adherents include, but are not limited to, talc, cornstarch, DL-leucine, sodium lauryl sulfate and metallic stearates. Talc is a preferred anti-adherent or glidant used, for example, to reduce formulation sticking to equipment surfaces and also to reduce static in the blend. Talc, if present, constitutes about 0.1% to about 10%, more preferably about 0.25% to about 5%, and still more preferably about 0.5% to about 2%, of the total weight of the pharmaceutical composition.

Glidants can be used to promote powder flow of a solid formulation. Suitable glidants include, but are not limited to, colloidal silicon dioxide, starch, talc, tribasic calcium phosphate, powdered cellulose and magnesium trisilicate. Colloidal silicon dioxide is particularly preferred.

Other excipients such as colorants, flavors and sweeteners are known in the pharmaceutical art and can be used in pharmaceutical compositions of the present invention. Tablets can be coated, for example with an enteric coating, or uncoated. Compositions of the invention can further comprise, for example, buffering agents.

Optionally, one or more effervescent agents can be used as disintegrants and/or to enhance organoleptic properties of pharmaceutical compositions of the invention. When present in pharmaceutical compositions of the invention to promote dosage form disintegration, one or more effervescent agents are preferably present in a total amount of about 30% to about 75%, and preferably about 45% to about 70%, for example about 60%, by weight of the pharmaceutical composition.

According to a particularly preferred embodiment of the invention, an effervescent agent, present in a solid dosage form in an amount less than that effective to promote disintegration of the dosage form, provides improved dispersion of the API in an aqueous medium. Without being bound by theory, it is believed that the effervescent agent is effective to accelerate dispersion of the API, from the dosage form in the gastrointestinal tract, thereby further enhancing absorption and rapid onset of therapeutic effect. When present in a pharmaceutical composition of the invention to promote intragastrointestinal dispersion but not to enhance disintegration, an effervescent agent is preferably present in an amount of about 1% to about 20%, more preferably about 2.5% to about 15%, and still more preferably about 5% to about 10%, by weight of the pharmaceutical composition.

An "effervescent agent" herein is an agent comprising one or more compounds which, acting together or individually, evolve a gas on contact with water. The gas evolved is generally oxygen or, most commonly, carbon dioxide. Preferred effervescent agents comprise an acid and a base that react in the presence of water to generate carbon dioxide gas. Preferably, the base comprises an alkali metal or alkaline earth metal carbonate or bicarbonate and the acid comprises an aliphatic carboxylic acid.

Non-limiting examples of suitable bases as components of effervescent agents useful in the invention include carbonate salts (e.g., calcium carbonate), bicarbonate salts (e.g., sodium bicarbonate), sesquicarbonate salts, and mixtures thereof. Calcium carbonate is a preferred base.

Non-limiting examples of suitable acids as components of effervescent agents and/or solid acids useful in the invention include citric acid, tartaric acid (as D-, L-, or D/L-tartaric acid), malic acid, maleic acid, fumaric acid, adipic acid, succinic acid, acid anhydrides of such acids, acid salts of such acids, and mixtures thereof. Citric acid is a preferred acid.

In a preferred embodiment of the invention, where the effervescent agent comprises an acid and a base, the weight ratio of the acid to the base is about 1:100 to about 100:1, more preferably about 1:50 to about 50:1, and still more preferably about 1:10 to about 10:1. In a further preferred embodiment of the invention, where the effervescent agent comprises an acid and a base, the ratio of the acid to the base is approximately stoichiometric.

Excipients which solubilize metal salts of APIs typically have both hydrophilic and hydrophobic regions, or are preferably amphiphilic or have amphiphilic regions. One type of amphiphilic or partially-amphiphilic excipient comprises an amphiphilic polymer or is an amphiphilic polymer. A specific amphiphilic polymer is a polyalkylene glycol, which is commonly comprised of ethylene glycol and/or propylene glycol subunits. Such polyalkylene glycols can be esterified at their termini by a carboxylic acid, ester, acid anhyride or other suitable moiety. Examples of such excipients include poloxamers (symmetric block copolymers of ethylene glycol and propylene glycol; e.g., poloxamer 237), polyalkyene glycolated esters of tocopherol (including esters formed from a di- or multi-functional carboxylic acid; e.g., d-alpha-tocopherol polyethylene glycol-1000

succinate), and macrogolglycerides (formed by alcoholysis of an oil and esterification of a polyalkylene glycol to produce a mixture of mono-, di- and tri-glycerides and mono- and di-esters; e.g., stearoyl macrogol-32 glycerides). Such pharmaceutical compositions are advantageously administered orally.

Pharmaceutical compositions of the present invention can comprise about 10% to about 50%, about 25% to about 50%, about 30% to about 45%, or about 30% to about 35% by weight of API; about 10% to about 50%, about 25% to about 50%, about 30% to about 45%, or about 30% to about 35% by weight of a an excipient which inhibits crystallization; and about 5% to about 50%, about 10% to about 40%, about 15% to about 35%, or about 30% to about 35% by weight of a binding agent. In one example, the weight ratio of the API to the excipient which inhibits crystallization to binding agent is about 1 to 1 to 1.

Solid dosage forms of the invention can be prepared by any suitable process, not limited to processes described herein.

An illustrative process comprises (a) a step of blending a salt of the invention with one or more excipients to form a blend, and (b) a step of tableting or encapsulating the blend to form tablets or capsules, respectively.

In a preferred process, solid dosage forms are prepared by a process comprising (a) a step of blending an API salt of the invention with one or more excipients to form a blend, (b) a step of granulating the blend to form a granulate, and (c) a step of tableting or encapsulating the blend to form tablets or capsules respectively. Step (b) can be accomplished by any dry or wet granulation technique known in the art, but is preferably a dry granulation step. A salt of the present invention is advantageously granulated to form particles of about 1 micrometer to about 100 micrometer, about 5 micrometer to about 50 micrometer, or about 10 micrometer to about 25 micrometer. One or more diluents, one or more disintegrants and one or more binding agents are preferably added, for example in the blending step, a wetting agent can optionally be added, for example in the granulating step, and one or more disintegrants are preferably added after granulating but before tableting or encapsulating. A lubricant is preferably added before tableting. Blending and granulating can be performed independently under low or high shear. A process is preferably selected that forms a granulate that is uniform in API content, that

readily disintegrates, that flows with sufficient ease so that weight variation can be reliably controlled during capsule filling or tableting, and that is dense enough in bulk so that a batch can be processed in the selected equipment and individual doses fit into the specified capsules or tablet dies.

In an alternative embodiment, solid dosage forms are prepared by a process that includes a spray drying step, wherein the API is suspended with one or more excipients in one or more sprayable liquids, preferably a non-protic (e.g., non-aqueous or non-alcoholic) sprayable liquid, and then is rapidly spray dried over a current of warm air.

A granulate or spray dried powder resulting from any of the above illustrative processes can be compressed or molded to prepare tablets or encapsulated to prepare capsules. Conventional tableting and encapsulation techniques known in the art can be employed. Where coated tablets are desired, conventional coating techniques are suitable.

Excipients for tablet compositions of the invention are preferably selected to provide a disintegration time of less than about 30 minutes, preferably about 25 minutes or less, more preferably about 20 minutes or less, and still more preferably about 15 minutes or less, in a standard disintegration assay.

In another embodiment of the present invention, a pharmaceutical composition comprising modafinil and an additional API can be prepared. The modafinil and the additional API can be in the form of a co-crystal, or may be included as a mixture or a combination of active pharmaceutical ingredients. For example, a composition can comprise modafinil and caffeine as a combination. A composition comprising modafinil and caffeine can be used as a therapeutic agent to treat the same conditions as modafinil. In such a composition comprising modafinil and caffeine, the caffeine can yield a quick release characteristic (small T_{max} relative to modafinil) to the dissolution profile while the modafinil causes the therapeutic effect to be present for hours after administration. For example, the T_{max} of caffeine may be 0.001, 0.01, 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, or 0.8 times that of modafinil. Combination therapies comprise the administration of two or more APIs in the same formulation, or in two or more co-administered formulations. The APIs can be administered together at the same time, or individually at specified intervals.

In a further embodiment, the present invention provides a novel polymorph of R-(-)-modafinil. In a specific embodiment, the present invention provides Forms I, II, III, IV, and V of R-(-)-modafinil. The present invention also provides a method of making a polymorph of R-(-)-modafinil.

In a further embodiment, the present invention provides a method of making a polymorph of R-(-)-modafinil, comprising:

(a) providing R-(-)-modafinil; and

(b) crystallizing the polymorph of R-(-)-modafinil from an appropriate solvent.

In a further embodiment, a polymorph of R-(-)-modafinil is crystallized from an organic solvent. In a particular embodiment, the organic solvent is ethanol. In another embodiment, a mixed solvent system is used to crystallize a polymorph of R-(-)-modafinil. Mixed solvent systems can be, for example, ethanol and isopropyl alcohol, or ethyl acetate and ethanol. In a further embodiment, the crystallization in step (b) is completed via thermal recrystallization. In a further embodiment, the crystallization in step (b) is completed via evaporation of the solvent.

Uses for modafinil are well known in the art and include the treatment of narcolepsy, multiple sclerosis related fatigue, infertility, eating disorders, attention deficit hyperactivity disorder (ADHD), Parkinson's disease, incontinence, sleep apnea, or myopathies. The dosage and administration for modafinil compositions of the present invention can be determined using routine methods in the art but will generally fall between about 50 and about 700 mg/day.

EXAMPLES

General Methods for the Preparation of Co-Crystals

a) High Throughput crystallization using the CrystalMax™ platform

CrystalMax™ comprises a sequence of automated, integrated high throughput robotic stations capable of rapid generation, identification and characterization of polymorphs, salts, and co-crystals of APIs and API candidates. Worksheet generation and combinatorial mixture design is carried out using proprietary design software

Architect™. Typically, an API or an API candidate is dispensed from an organic solvent into tubes and dried under a stream of nitrogen. Salts and/or co-crystal formers may also be dispensed and dried in the same fashion. Water and organic solvents may be combinatorially dispensed into the tubes using a multi-channel dispenser. Each tube in a 96-tube array is then sealed within 15 seconds of combinatorial dispensing to avoid solvent evaporation. The mixtures are then rendered supersaturated by heating to 70 degrees C for 2 hours followed by a 1 degree C/minute cooling ramp to 5 degrees C. Optical checks are then conducted to detect crystals and/or solid material. Once a solid has been identified in a tube, it is isolated through aspiration and drying. Raman spectra are then obtained on the solids and cluster classification of the spectral patterns is performed using proprietary software (Inquire™).

b) Crystallization from solution

Co-crystals may be obtained by dissolving the separate components in a solvent and adding one to the other. The co-crystal may then precipitate or crystallize as the solvent mixture is evaporated slowly. The co-crystal may also be obtained by dissolving the two components in the same solvent or a mixture of solvents. The co-crystal may also be obtained by seeding a saturated solution of the two components and seeding with a ground mixture of the co-crystal.

c) Crystallization from the melt (Co-melting)

A co-crystal may be obtained by melting the two components together (i.e., co-melting) and allowing recrystallization to occur. In some cases, an anti-solvent may be added to facilitate crystallization.

d) Thermal microscopy

A co-crystal may be obtained by melting the higher melting component on a glass slide and allowing it to recrystallize. The second component is then melted and is also allowed to recrystallize. The co-crystal may form as a separated phase/band in between the eutectic bands of the two original components.

e) Mixing and/or grinding

A co-crystal may be obtained by mixing or grinding two components together in the solid state. For example, Example 12 describes the synthesis of a modafinil:1-hydroxy-2-naphthoic acid co-crystal obtained by milling with the addition of a small amount of an appropriate solvent. Similarly, Example 5 describes the synthesis of a modafinil:citric acid monohydrate co-crystal obtained by milling both with and without the addition of a small amount of an appropriate solvent. In one embodiment, a co-crystal is prepared via milling or grinding modafinil with a co-crystal former. In another embodiment, a co-crystal is prepared via milling or grinding modafinil, a co-crystal former, and a small amount of solvent.

In another embodiment, a co-crystal is prepared with the addition of solvent, without the addition of solvent, or both. Solvents used in such a co-crystallization process can be, for example, but not limited to, acetone, methanol, ethanol, isopropyl alcohol, ethyl acetate, isopropyl acetate, nitromethane, dichloromethane, chloroform, toluene, propylene glycol, dimethyl sulfoxide (DMSO), dimethyl formamide (DMF), diethyl ether (ether), ethyl formate, hexane, acetonitrile, or another organic solvent including alcohols.

f) Co-sublimation

A co-crystal may be obtained by co-subliming a mixture of an API and a co-crystal former in the same sample cell as an intimate mixture either by heating, mixing or placing the mixture under vacuum. A co-crystal may also be obtained by co-sublimation using a Kneudsen apparatus where the API and the co-crystal former are contained in separate sample cells, connected to a single cold finger, each of the sample cells is maintained at the same or different temperatures under a vaccum atmosphere in order to co-sublime the two components onto the cold-finger forming the desired co-crystal.

Analytical Methods

Differential scanning calorimetric (DSC) analysis of the samples was performed using a Q1000 Differential Scanning Calorimeter (TA Instruments, New Castle, DE,

U.S.A.), which uses Advantage for QW-Series, version 1.0.0.78, Thermal Advantage Release 2.0 (2001 TA Instruments-Water LLC). In addition, the analysis software used was Universal Analysis 2000 for Windows 95/98/2000/NT, version 3.1E;Build 3.1.0.40 (2001 TA Instruments-Water LLC).

For the DSC analysis, the purge gas used was dry nitrogen, the reference material was an empty aluminum pan that was crimped, and the sample purge was 50 mL/minute.

DSC analysis of the sample was performed by placing the modafinil sample in an aluminum pan with a crimped pan closure. The starting temperature was typically 20 degrees C with a heating rate of 10 degrees C/minute, and the ending temperature was 200 degrees C. All reported DSC transitions represent the temperature of endothermic or exothermic transition at their respective peaks with an error of +/- 2 degrees C, unless otherwise indicated.

Thermogravimetric analysis (TGA) of samples was performed using a Q500 Thermogravimetric Analyzer (TA Instruments, New Castle, DE, U.S.A.), which uses Advantage for QW-Series, version 1.0.0.78, Thermal Advantage Release 2.0 (2001 TA Instruments-Water LLC). In addition, the analysis software used was Universal Analysis 2000 for Windows 95/98/2000/NT, version 3.1E;Build 3.1.0.40 (2001 TA Instruments-Water LLC).

For the TGA experiments, the purge gas used was dry nitrogen, the balance purge was 40 mL/minute N_2, and the sample purge was 60 mL/minute N_2.

TGA was performed on the sample by placing the modafinil sample in a platinum pan. The starting temperature was typically 20 degrees C with a heating rate of 10 degrees C/minute, and the ending temperature was 300 degrees C.

A powder X-ray diffraction (PXRD) pattern for the samples was obtained using a D/Max Rapid, Contact (Rigaku/MSC, The Woodlands, TX, U.S.A.), which uses as its control software RINT Rapid Control Software, Rigaku Rapid/XRD, version 1.0.0 (1999 Rigaku Co.). In addition, the analysis software used were RINT Rapid display software, version 1.18 (Rigaku/MSC), and JADE XRD Pattern Processing, versions 5.0 and 6.0 ((1995-2002, Materials Data, Inc.).

For the PXRD analysis, the acquisition parameters were as follows: source was Cu with a K line at 1.5406 Å; x-y stage was manual; collimator size was 0.3 mm;

capillary tube (Charles Supper Company, Natick, MA, U.S.A.) was 0.3 mm ID; reflection mode was used; the power to the X-ray tube was 46 kV; the current to the X-ray tube was 40 mA; the omega-axis was oscillating in a range of 0-5 degrees at a speed of 1 degree/minute; the phi-axis was spinning at an angle of 360 degrees at a speed of 2 degrees/second; 0.3 mm collimator; the collection time was 60 minutes; the temperature was room temperature; and the heater was not used. The sample was presented to the X-ray source in a boron rich glass capillary.

In addition, the analysis parameters were as follows: the integration 2-theta range was 2-60 degrees; the integration chi range was 0-360 degrees; the number of chi segments was 1; the step size used was 0.02; the integration utility was cylint; normalization was used; dark counts were 8; omega offset was 180; and chi and phi offsets were 0.

PXRD diffractograms were also acquired via the Bruker AXS D8 Discover X-ray Diffractometer. This instrument was equipped with GADDS™ (General Area Diffraction Detection System), a Bruker AXS HI-STAR Area Detector at a distance of 15.05 cm as per system calibration, a copper source (Cu/K_{α} 1.54056 angstroms), automated x-y-z stage, and 0.5mm collimator. The sample was compacted into pellet form and mounted on the x-y-z stage. A diffractogram was acquired under ambient conditiona at a powder setting of 40kV and 40mA in reflection mode while the sampleremained stationary. The exposure time was varied and specified for each sample. The diffractogram obtained underwent a spatial remapping procedure to account for the geometrical pincushion distortion of the area detector then integrated along chi from -118.8 to -61.8 degrees and 2-theta 2.1-37 degrees at a step size of 0.02 degrees with normalization set to bin normalize.

The relative intensity of peaks in a diffractogram is not necessarily a limitation of the PXRD pattern because peak intensity can vary from sample to sample, e.g., due to crystalline impurities. Further, the angles of each peak can vary by about +/- 0.1 degrees, preferably +/- 0.05. The entire pattern or most of the pattern peaks may also shift by about +/- 0.1 degree due to differences in calibration, settings, and other variations from instrument to instrument and from operator to operator.

For PXRD data herein, including Tables and Figures, each composition of the present invention may be characterized by any one, any two, any three, any four, any five, any six, any seven, or any eight or more of the 2 theta angle peaks. Any one, two, three, four, five, or six DSC transitions can also be used to characterize the compositions of the present invention. The different combinations of the PXRD peaks and the DSC transitions can also be used to characterize the compositions.

Data for the co-crystals are shown in Table IV and in the Figures.

Example 1

Modafinil:Malonic acid Co-crystal

Using a 250 mg/mL modafinil-acetic acid solution, malonic acid was dissolved on a hotplate (about 67 degrees C) at a 1:2 modafinil to malonic acid ratio. The mixture was dried under flowing nitrogen overnight. A powdery white solid was produced. After further drying for 1 day, acetic acid was removed (as determined by TGA) and the crystal structure, as determined by PXRD, remained the same. PXRD data for the modafinil:malonic acid (1:1) co-crystal are listed in Table IV, and the diffractogram is shown in Figure 1 (Data as collected). DSC showed an endothermic transition at 106.23 degrees C, and the thermogram is shown in Figure 2. TGA thermogram is shown in Figure 3. Figures 4A and 4B show a Raman spectrum of the modafinil:malonic acid co-crystal and three Raman spectra of modafinil, malonic acid, and the co-crystal, respectively. Figures 5A and 5B show an IR spectrum of the modafinil:malonic acid co-crystal and three IR spectra of modafinil, malonic acid, and the co-crystal, respectively. The modafinil:malonic acid co-crystal can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 1 including, but not limited to, 5.00, 9.17, 10.08, 16.81, 18.26, 19.43, 21.36, 21.94, 22.77, 24.49, 25.63, 26.37, and 28.45 degrees 2-theta.

The modafinil:malonic acid co-crystal was also prepared by grinding the API and co-crystal former together. 2.50 g of modafinil was mixed with 1.01 g of malonic acid in a large mortar and pestle (malonic acid added in increments over 7 days with about a 1:1.05 ratio made on the first day and increments added over the next seven days which resulted in a 1:2 modafinil:malonic acid ratio). The mixture was ground for 45 minutes

initially and 20 minutes each time more malonic acid was added. On the seventh day the mixture of co-crystal and starting components was heated in a sealed 20 mL vial at 80 degrees C for about 35 minutes to facilitate completion of the co-crystal formation. PXRD analysis of the resultant material was completed, and is shown in Figure 6 (background subtracted). The modafinil:malonic acid co-crystal can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 6 including, but not limited to, 5.11, 9.35, 16.87, 18.33, 19.53, 21.38, 22.05, 22.89, 23.57, 24.73, 25.19, and 28.59 degrees 2-theta. Single crystal data of the modafinil:malonic acid co-crystal were acquired and are reported below. Figure 7 shows a packing diagram of the modafinil:malonic acid.

Crystal data: $C_{18}H_{19}NO_6S$, M = 377.40, monoclinic C2/c; a = 18.728(8) angstroms, b = 5.480(2) angstroms, c = 33.894(13) angstroms, alpha = 90 degrees, beta = 91.864(9) degrees, gamma = 90 degrees, T = 100(2) K, Z = 8, D_c = 1.442 Mg/m^3, U = 3477(2) cubic angstroms, λ = 0.71073 angstroms, 6475 reflections measured, 3307 unique (R_{int} = 0.1567). Final residuals were R_1 = 0.1598, wR_2 = 0.3301 for I>2sigma(I), and R_1 = 0.2544, wR_2 = 0.3740 for all 3307 data.

Other methods were also used to prepare the modafinil:malonic acid co-crystal. A third preparation was performed by placing equimolar amounts of modafinil (30 mg, 0.0001 mol) and malonic acid in a stainless steel vial. 20 microliters of acetone was added to the vial. The vial was then placed in a grinder (wig-l-bug, Bratt Technologies, 115V/60Hz) and the solid mixture was milled for 5 minutes. The resultant powder was then collected and characterized using PXRD and DSC. In yet another preparation of the modafinil:malonic acid co-crystal, the third preparation above was completed without the addition of solvent. All of the above methods with malonic acid were shown to yield the same co-crystal via PXRD and DSC analysis.

Example 2

Modafinil:Glycolic acid Co-crystal

Modafinil (1 mg, 0.0037mmol) and glycolic acid (0.30 mg, 0.0037 mmol) were dissolved in acetone (400 microliters). The solution was allowed to evaporate to dryness and the resulting solid was characterized using PXRD. PXRD data for the

modafinil:glycolic acid co-crystal are listed in Table IV. See Figures 8A and 8B. Figure 8A shows the PXRD diffractogram after subtraction of background noise. Figure 8B shows the raw PXRD data as collected.

An alternative method for the preparation of modafinil:glycolic acid co-crystals was also completed. To a solution of modafinil (1 mg, 0.0037 mmol) dissolved in a mixture of acetone and methanol (3:1, 100 microliters) was added glycolic acid (0.28 mg, 0.0037 mmol) dissolved in methanol (50 microliters). The solvent was then evaporated to dryness under a flow of nitrogen to give a mixture of the two starting components. Acetone (200 microliters) was then added to the mixture and it was heated to 70 degrees C and maintained at 70 degrees C for 2 hours. The sample was then cooled to 5 degrees C and maintained at that temperature for 1 day. After 1 day, the cap was removed from the vial and the solvent was evaporated to dryness to give a modafinil:glycolic acid co-crystal as a colorless solid. The modafinil:glycolic acid co-crystal was characterized by PXRD. The modafinil:glycolic acid co-crystal can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 8A including, but not limited to, 9.51, 14.91, 15.97, 19.01, 20.03, 21.59, 22.75, 25.03, and 25.71 degrees 2-theta. The modafinil:glycolic acid co-crystal can, likewise, be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 8B including, but not limited to, 9.53, 14.93, 15.99, 19.05, 20.05, 21.61, 22.77, and 25.05 degrees 2-theta.

Example 3

Modafinil:Maleic acid Co-crystal

Using a 250 mg/ml modafinil in acetic acid solution, maleic acid was dissolved on a hotplate (about 67 degrees C) at a 2:1 modafinil to maleic acid ratio. The mixture was dried under flowing nitrogen overnight. A clear amorphous material remained. Solids began to grow after 2 days stored in a sealed vial at room temperature. The resulting solid was characterized using PXRD (See Figures 9A and 9B). Figure 9A shows the PXRD diffractogram after subtraction of background noise. Figure 9B shows the raw PXRD data. PXRD data for the modafinil:maleic acid co-crystal are listed in Table IV.

The modafinil:maleic acid co-crystal can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 9A including, but not limited to, 4.69, 6.15, 9.61, 10.23, 15.65, 16.53, 17.19, 18.01, 19.97, 21.83, and 22.45 degrees 2-theta. The modafinil:maleic acid co-crystal can, likewise, be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 9B including, but not limited to, 4.69, 6.17, 9.63, 10.25, 15.67, 16.53, 17.21, 18.05, 19.99, 21.85, and 22.47 degrees 2-theta.

Example 4

Modafinil:L-tartaric acid Co-crystal

A modafinil:L-tartaric acid co-crystal was prepared by mixing 10.12 mg of modafinil and 5.83 mg of L-tartaric acid in 2 mL of methanol. All solids were dissolved at room temperature. The solution was then left to evaporate in air. The clear and viscous material was dried further under flowing nitrogen for 2 days, and then capped. After 6 days, a small amount of white solid formed. 1 day after the first solids are seen approximately 60 % of the remaining clear amorphous volume converted to the solid form. A sample of this material was analyzed by PXRD (See Figure 10). The modafinil:L-tartaric acid co-crystal can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 10 including, but not limited to, 6.10, 7.36, 9.38, 14.33, 16.93, 17.98, 18.81, 20.15, 20.71, 22.49, and 25.04 degrees 2-theta.

Example 5

Modafinil:Citric acid Co-crystal

Modafinil (25.3 mg, 93 mmol) and citric acid monohydrate (26.8 mg, 128 mmol) were ground together for 3 minutes. 1 mg of the resulting mixture was then dissolved in acetone (100 microliters) and heated to 70 degrees C and maintained at that temperature for 2 hours. The solution was then cooled to 5 degrees C and was left at that temperature for 2 days. After 2 days the cap was removed from the vial and one drop of water was added. The solvent was then evaporated to give a modafinil:citric acid monohydrate co-crystal as a colorless solid. The modafinil:citric acid monohydrate co-crystal was

characterized by PXRD (See Figure 11, background subtracted). The modafinil:citric acid co-crystal can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 11 including, but not limited to, 5.29, 7.29, 9.31, 12.41, 13.29, 17.29, 17.97, 18.79, 21.37, and 23.01 degrees 2-theta.

Other methods were also used to prepare the modafinil:citric acid monohydrate co-crystal. A second preparation was performed by placing equimolar amounts of modafinil (30 mg, 0.0001 mol) and citric acid monohydrate in a stainless steel vial. 20 microliters of acetone was added to the vial. The vial was then placed in a grinder (wig-l-bug, Bratt Technologies, 115V/60Hz) and the solid mixture was milled for 5 minutes. The resultant powder was then collected and characterized using PXRD and DSC. In yet another preparation of the modafinil:citric acid monohydrate co-crystal, the second preparation above was completed without the addition of solvent. All of the above methods with citric acid monohydrate were shown to yield the same co-crystal via PXRD and DSC analysis.

Example 6

Modafinil:Succinic acid Co-crystal

Modafinil (25mg, 90 mmol) and succinic acid (10.6 mg, 90 mmol) were placed in a glass vial and dissolved in methanol (20 microliters). The resulting solution was heated at 70 degrees C for 2 hours and then cooled to 5 degrees C and maintained at that temperature for 2 days. After 2 days, the cap was removed from the vial and the solvent was evaporated at 65 degrees C to give a 2:1 modafinil:succinic acid co-crystal as a colorless solid. The co-crystal is a 2:1 co-crystal comprising two moles of modafinil for every mole of succinic acid. The modafinil:succinic acid co-crystal was characterized by PXRD and DSC. (See Figures 12A, 12B, and 13) Figure 12A shows the PXRD diffractogram after subtraction of background noise. Figure 12B shows the raw PXRD data. Figure 13 shows the DSC thermogram.

An alternative method for the preparation of modafinil:succinic acid co-crystals was also completed. 49.7 mg of modafinil and 21.6 mg of succinic acid was charged to a round bottom flask to make a 1:1 mixture. Add 1.5 mL of methanol and dissolve at 65 degrees C using a hot water bath. Seed crystals of modafinil:succinic acid

co-crystal from the above preparation were added to the flask. The methanol was then evaporated using a rotary evaporator and a 65 degrees C hot water bath. PXRD of the collected solid confirms the synthesis of the modafinil:succinic acid co-crystal. The modafinil:succinic acid co-crystal can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 12A including, but not limited to, 5.45, 9.93, 15.85, 17.97, 18.73, 19.95, 21.33, 21.93, 23.01, and 25.11 degrees 2-theta. The modafinil:succinic acid co-crystal can, likewise, be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 12B including, but not limited to, 5.45, 9.93, 15.87, 17.99, 18.75, 19.95, 21.95, 23.03, and 25.07 degrees 2-theta. Single crystal data of the modafinil:succinic acid co-crystal were acquired and are reported below. Figure 14 shows a packing diagram of the modafinil:succinic acid co-crystal.

Crystal data: $C_{17}H_{18}NO_4S$, triclinic P-1; a = 5.672(4) angstroms, b = 8.719(6) angstroms, c = 16.191(11) angstroms, alpha = 93.807(14) degrees, beta = 96.471(17) degrees, gamma = 92.513(13) degrees, T = 100(2) K, Z = 2, D_c = 1.392 Mg/m^3, U = 792.8(9) cubic angstroms, λ = 0.71073 angstroms, 2448 reflections measured, 1961 unique (R_{int} = 0.0740). Final residuals were R_1 = 0.1008, wR_2 = 0.2283 for I>2sigma(I), and R_1 = 0.1593, wR_2 = 0.2614 for all 1961 data.

A third method was also used to prepare the modafinil:succinic acid co-crystal. This method was performed by placing equimolar amounts of modafinil (30 mg, 0.0001 mol) and succinic acid in a stainless steel vial. 20 microliters of acetone was added to the vial. The vial was then placed in a grinder (wig-l-bug, Bratt Technologies, 115V/60Hz) and the solid mixture was milled for 5 minutes. The resultant powder was then collected and characterized using PXRD and DSC. All of the above methods with succinic acid were shown to yield the same co-crystal via PXRD and DSC analysis.

Example 7

Modafinil:DL-tartaric acid Co-crystal

A suspsension of modafinil (162 mg; 0.591 mmol) and DL-tartaric acid (462 mg; 3.08 mmol) in acetone (10 mL) was heated to reflux for 1 minute. The undissolved DL-

tartaric acid was filtered off while the suspension was still hot through a 0.2 micrometer PTFE filter. The remaining solution was allowed to cool to room temperature then to 0 degrees C for 1 hour. After 1 hour, large colorless crystals were observed. The mother liquor was decanted and the solid was allowed to air dry. The modafinil:DL-tartaric acid co-crystal can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 15 including, but not limited to, 4.75, 9.53, 10.07, 15.83, 17.61, 19.37, 20.25, 21.53, 22.55, and 23.75 degrees 2-theta (as collected).

Example 8

Modafinil:Fumaric acid Co-crystal (Form I)

Equimolar amounts of modafinil (30 mg, 0.0001 mol) and fumaric acid were placed in a stainless steel vial. 20 microliters of acetone was added to the vial. The vial was then placed in a grinder (wig-l-bug, Bratt Technologies, 115V/60Hz) and the solid mixture was milled for 5 minutes. The resultant powder was then collected and characterized as modafinil:fumaric acid co-crystal (Form I) using PXRD (See Figure 16). The co-crystal is a 2:1 co-crystal comprising two moles of modafinil for every mole of fumaric acid. The modafinil:fumaric acid co-crystal (Form I) can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 16 including, but not limited to, 5.45, 9.95, 10.91, 15.93, 18.03, 18.81, 19.93, 20.25, 21.37, 21.95, 23.09, and 25.01 degrees 2-theta (as collected). Single crystal data of the modafinil:fumaric acid co-crystal (Form I) were acquired and are reported below. Figure 17 shows a packing diagram of the modafinil:fumaric acid co-crystal (Form I).

Crystal data: $C_{17}H_{17}NO_4S$, M = 331.38, triclinic P-1; a = 5.7000(15) angstroms, b = 8.735(2) angstroms, c = 16.204(4) angstroms, alpha = 93.972(6) degrees, beta = 97.024(6) degrees, gamma = 93.119(7) degrees, T = 100(2) K, Z = 2, D_c = 1.381 Mg/m^3, U = 797.2(4) cubic angstroms, λ = 0.71073 angstroms, 4047 reflections measured, 2615 unique (R_{int} = 0.0475). Final residuals were R_1 = 0.0784, wR_2 = 0.1584 for I>2sigma(I), and R_1 = 0.1154, wR_2 = 0.1821 for all 2615 data.

Example 9

Modafinil:Fumaric acid Co-crystal (Form II)

Equimolar amounts of modafinil (30 mg, 0.0001 mol) and fumaric acid were placed in a stainless steel vial. 20 microliters of acetone was added to the vial. The vial was then placed in a grinder (wig-l-bug, Bratt Technologies, 115V/60Hz) and the solid mixture was milled for 5 minutes. The resultant powder was then collected and characterized as modafinil:fumaric acid co-crystal (Form II) using PXRD (See Figure 18). The modafinil:fumaric acid co-crystal (Form II) can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 18 including, but not limited to, 6.47, 8.57, 9.99, 13.89, 14.53, 16.45, 17.13, 17.51, 18.39, 20.05, 20.79, 25.93, and 27.95 degrees 2-theta (as collected).

Example 10

Modafinil:Gentisic acid Co-crystal

Equimolar amounts of modafinil (30 mg, 0.0001 mol) and gentisic acid were placed in a stainless steel vial. 20 microliters of acetone was added to the vial. The vial was then placed in a grinder (wig-l-bug, Bratt Technologies, 115V/60Hz) and the solid mixture was milled for 5 minutes. The resultant powder was then collected and characterized using PXRD (See Figure 19). The modafinil:gentisic acid co-crystal can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 19 including, but not limited to, 6.96, 12.92, 14.76, 17.40, 18.26, 20.10, 20.94, 23.46, and 24.36 degrees 2-theta (as collected).

Example 11

Modafinil:Oxalic acid Co-crystal

A preparation of modafinil:oxalic acid co-crystal was performed by placing equimolar amounts of modafinil (30 mg, 0.0001 mol) and oxalic acid in a stainless steel vial. 20 microliters of acetone was added to the vial. The vial was then placed in a grinder (wig-l-bug, Bratt Technologies, 115V/60Hz) and the solid mixture was milled for 5 minutes. The resultant powder was then collected and characterized using PXRD (See Figure 20). In another preparation of the modafinil:oxalic acid co-crystal, the preparation above was completed without the addition of solvent. Both methods were shown to yield the same co-crystal via PXRD analysis. The modafinil:oxalic acid co-crystal can be

characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 20 including, but not limited to, 5.98, 13.68, 14.80, 17.54, 19.68, 21.12, 21.86, and 28.90 degrees 2-theta (as collected).

Example 12

Modafinil:1-hydroxy-2-naphthoic acid Co-crystal

Modafinil (30 mg, 0.0001 mol) and 1-hydroxy-2-naphthoic acid (21 mg, 0.0001 mol) were placed in a stainless steel vial. 20 microliters of acetone was added to the vial. The vial was then placed in a grinder (wig-l-bug, Bratt Technologies, 115V/60Hz) and the solid mixture was milled for 5 minutes. The resultant powder was then collected and characterized using PXRD (See Figure 21). The modafinil:1-hydroxy-2-naphthoic acid co-crystal can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 21 including, but not limited to, 5.72, 7.10, 11.48, 14.16, 15.66, 17.92, 19.18, 20.26, 21.28, 21.94, 24.38, and 26.86 degrees 2-theta (as collected).

Example 13

R-(-)-Modafinil:Malonic acid Co-crystal

R-(-)-modafinil:malonic acid co-crystal was prepared by grinding R-(-)-modafinil (29.7 mg, 0.109 mmol) with malonic acid (11.9 mg, 0.114 mmol). The ground mixture was then heated to 80 degrees C for 10 minutes. The powder was analyzed by PXRD and DSC (See Figures 22 and 23, respectively). The PXRD pattern confirms that the co-crystal was made and shows many similarities to the PXRD pattern for the racemic modafinil:malonic acid co-crystal. The R-(-)-modafinil:malonic acid co-crystal can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 22 including, but not limited to, 5.04, 9.26, 16.73, 18.23, 19.37, 21.90, 22.74, 24.44, and 25.67 degrees 2-theta (data as collected). The DSC showed a melting peak at 111.59 degrees C with a heat of fusion of 112.9 J/g.

Example 14

R-(-)-Modafinil:Succinic acid Co-crystal

R-(-)-modafinil:succinic acid co-crystal was prepared by grinding R-(-)-modafinil (30.9 mg, 0.113 mmol) with succinic acid (14.8 mg, 0.125 mmol). The ground mixture was then heated to 145 degrees C for 5 minutes. The powder was analyzed by PXRD and DSC (See Figures 24 and 25, respectively). The PXRD pattern confirms that the co-crystal was made and shows many similarities to the PXRD pattern for the racemic modafinil:succinic acid co-crystal made from solution. The R-(-)-modafinil:succinic acid co-crystal can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 24 including, but not limited to, 5.36, 9.83, 15.80, 17.88, 18.70, 19.87, 21.21, 21.85, and 25.96 degrees 2-theta (data as collected). The DSC showed a melting peak at 143.4 degrees C with a heat of fusion of 140.7 J/g.

Example 15

R-(-)-Modafinil:Citric acid Co-crystal

R-(-)-modafinil:citric acid co-crystal was prepared by grinding R-(-)-modafinil (30.0 mg, 0.110 mmol) with citric acid monohydrate (27.1 mg, 0.129 mmol). The powder was analyzed by PXRD and DSC (See Figures 26 and 27, respectively). The PXRD pattern confirms that the co-crystal was made and shows many similarities to the PXRD pattern for the racemic modafinil:citric acid co-crystal. The R-(-)-modafinil:citric acid co-crystal can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 26 including, but not limited to, 5.18, 7.23, 9.23, 12.32, 13.23, 17.25, 17.92, 18.76, 20.25, 21.30, and 23.71 degrees 2-theta (data as collected). The DSC showed a melting peak at 111.59 degrees C with a heat of fusion of 112.9 J/g.

Example 16

R-(-)-Modafinil:DL-tartaric acid Co-crystal

Equimolar amounts of R-(-)-modafinil (30 mg, 0.0001 mol) and DL-tartaric acid were placed in a stainless steel vial. 20 microliters of acetone was added to the vial. The

vial was then placed in a grinder (wig-l-bug, Bratt Technologies, 115V/60Hz) and the solid mixture was milled for 5 minutes. The resultant powder was then collected and characterized using PXRD and DSC (See Figures 28 and 29, respectively). The R-(-)-modafinil:DL-tartaric acid co-crystal can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 28 including, but not limited to, 4.67, 15.41, 17.97, 19.46, 20.50, 22.91, and 24.63 degrees 2-theta (as collected). Endothermic transitions were present at about 107, 152, and 187 degrees C.

Example 17

R-(-)-Modafinil:1-hydroxy-2-naphthoic acid Co-crystal

Equimolar amounts of R-(-)-modafinil (30 mg, 0.0001 mol) and 1-hydroxy-2-naphthoic acid were placed in a stainless steel vial. 20 microliters of acetone was added to the vial. The vial was then placed in a grinder (wig-l-bug, Bratt Technologies, 115V/60Hz) and the solid mixture was milled for 5 minutes. The resultant powder was then collected and characterized using PXRD and DSC (See Figures 30 and 31, respectively). The R-(-)-modafinil:1-hydroxy-2-naphthoic acid co-crystal can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 30 including, but not limited to, 5.31, 8.95, 10.68, 12.15, 14.48, 21.27, 23.15, 24.50, 25.52, and 26.72 degrees 2-theta (as collected). Endothermic transitions were present at about 118 and 179 degrees C.

Example 18

R-(-)-Modafinil:Lauric acid Co-crystal

Equimolar amounts of R-(-)-modafinil (30 mg, 0.0001 mol) and lauric acid were placed in a stainless steel vial. 20 microliters of acetone was added to the vial. The vial was then placed in a grinder (wig-l-bug, Bratt Technologies, 115V/60Hz) and the solid mixture was milled for 5 minutes. The resultant powder was then collected and characterized using PXRD and DSC (See Figures 32 (bottom pattern) and 33, respectively). The R-(-)-modafinil:lauric acid co-crystal can be characterized by any one,

any two, any three, any four, any five, or any six or more of the peaks in Figure 32 including, but not limited to, 3.15, 7.17, 9.50, 10.25, 12.08, 14.30, 17.67, 19.14, 20.14, 21.43, 23.84, and 25.77 degrees 2-theta (as collected). Endothermic transitions were present at about 141 and 155 degrees C.

Example 19

R-(-)-Modafinil:Orotic acid Co-crystal

Equimolar amounts of R-(-)-modafinil (30 mg, 0.0001 mol) and orotic acid were placed in a stainless steel vial. 20 microliters of acetone was added to the vial. The vial was then placed in a grinder (wig-l-bug, Bratt Technologies, 115V/60Hz) and the solid mixture was milled for 5 minutes. The resultant powder was then collected and characterized using PXRD and DSC (See Figures 34 and 35, respectively). The R-(-)-modafinil:orotic acid co-crystal can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 34 including, but not limited to, 9.77, 14.61, 17.85, 20.52, 20.95, 24.03, 26.80, and 28.60 degrees 2-theta (as collected). Endothermic transitions were present at about 116, 130, and 169 degrees C.

Table IV: Co-crystals of Modafinil

Co-Crystal former	Representative PXRD Peaks (degrees 2-theta)
Malonic acid	5.00, 9.17, 10.08, 16.81, 18.26, 19.43, 21.36, 21.94, 22.77, 24.49, 25.63, 26.37, 28.45
Glycolic acid	9.53, 14.93, 15.99, 19.05, 20.05, 21.61, 22.77, 25.05
Maleic acid	4.69, 6.17, 9.63, 10.25, 15.67, 16.53, 17.21, 18.05, 19.99, 21.85, 22.47
L-tartaric acid	6.10, 7.36, 9.38, 14.33, 16.93, 17.98, 18.81, 20.15, 20.71, 22.49, 25.04
Citric acid	5.29, 7.29, 9.31, 12.41, 13.29, 17.29, 17.97, 18.79, 21.37, 23.01
Succinic acid	5.45, 9.93, 15.87, 17.99, 18.75, 19.95, 21.95, 23.03, 25.07
DL-tartaric acid	4.75, 9.53, 10.07, 15.83, 17.61, 19.37, 20.25, 21.53, 22.55, 23.75
Fumaric acid (Form I)	5.45, 9.95, 10.91, 15.93, 18.03, 18.81, 19.93, 20.25, 21.37, 21.95, 23.09, 25.01
Fumaric acid (Form II)	6.47, 8.57, 9.99, 13.89, 14.53, 16.45, 17.13, 17.51, 18.39, 20.05, 20.79, 25.93, 27.95
Gentisic acid	6.96, 12.92, 14.76, 17.40, 18.26, 20.10, 20.94, 23.46, 24.36
Oxalic acid	5.98, 13.68, 14.80, 17.54, 19.68, 21.12, 21.86, 28.90
1-hydroxy-2-naphthoic acid	5.72, 7.10, 11.48, 14.16, 15.66, 17.92, 19.18, 20.26, 21.28, 21.94, 24.38, 26.86
*Malonic acid	5.04, 9.26, 16.73, 18.23, 19.37, 21.90, 22.74, 24.44, 25.67
*Succinic acid	5.36, 9.83, 15.80, 17.88, 18.70, 19.87, 21.21, 21.85, 25.96
*Citric acid	5.18, 7.23, 9.23, 12.32, 13.23, 17.25, 17.92, 18.76, 20.25, 21.30, 23.71
*DL-tartaric acid	4.67, 15.41, 17.97, 19.46, 20.50, 22.91, 24.63

•1-hydroxy-2-naphthoic acid	5.31, 8.95, 10.68, 12.15, 14.48, 21.27, 23.15, 24.50, 25.52, 26.72
•Lauric acid	3.15, 7.17, 9.50, 10.25, 12.08, 14.30, 17.67, 19.14, 20.14, 21.43, 23.84, 25.77
•Orotic acid	9.77, 14.61, 17.85, 20.52, 20.95, 24.03, 26.80, 28.60
•Gentisic acid	7.07, 7.51, 9.07, 12.31, 16.03, 17.63, 18.39, 19.83, 21.27, 23.57, 26.93, 28.85

• = API is R-(-)-modafinil, all other co-crystals comprise racemic modafinil

Example 20

Acetic acid Solvate of Modafinil

12.9 mg modafinil was mixed with 40 microliters acetic acid. The mixture was heated at 50 degrees C to completely dissolve the solid. The solution was allowed to cool to room temperature, and left overnight, which yielded no precipitation. The solution was then evaporated under flowing nitrogen until precipitation was observed. The resulting solid was further dried under flowing nitrogen. Characterization of the product has been achieved via PXRD, TGA, DSC, and Raman spectroscopy. (See Figures 36-39, respectively) An alternative method for the preparation of the acetic acid solvate of modafinil was also completed. A sample of modafinil acetic acid solvate was prepared by dissolving 12.9 mg of the compound in 40 microliters acetic acid incubating at 65 degrees C for 30 minutes to dissolve, then cooling to 25 degrees C to incubate overnight. The sample was then evaporated to approximately 1/3 volume. After centrifugation of the sample, rapid nucleation and growth of crystals was observed. An additional 20 microliters of acetic acid was then added. The sample was heated at 50 degrees C until partial dissolution of the crystals was observed. The sample was then cooled to room temperature over a 1 hour period, then to 5 degrees C for 3 hours in an attempt to induce crystal growth. The sample was then dried under nitrogen gas. Rapid appearance of crystals was observed. The modafinil acetic acid solvate can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 36 including, but not limited to, 6.17, 9.63, 15.69, 17.97, 19.99, and 21.83 degrees 2-theta (data as collected).

Example 21

Tetrahydrofuran Solvate of Modafinil

The tetrahydrofuran (THF) solvate of modafinil was prepared by placing 10.4 mg of modafinil in 1 mL of tetrahydrofuran. The powder submerged in the tetrahydrofuran did not completely dissolve and was observed to convert, overnight, into long, fine, needle shaped crystals which were collected and analyzed by PXRD (See Figure 40). The modafinil tetrahydrofuran solvate can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 40 including, but not limited to, 6.97, 9.79, 10.97, 16.19, 19.03, 19.71, 20.59, 22.25, and 25.13 degrees 2-theta (data as collected).

Example 22

1,4-Dioxane Solvate of Modafinil

The 1,4-dioxane solvate of modafinil was prepared by placing 11.6 mg of modafinil in 1 mL of 1,4-dioxane. The powder submerged in the 1,4-dioxane was observed to convert, overnight, into long fine needle shaped crystals which were collected and analyzed by PXRD (See Figure 41). The modafinil 1,4-dioxane solvate can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 41 including, but not limited to, 6.93, 9.85, 10.97, 16.19, 18.97, 19.61, 20.33, 20.65, and 22.07 degrees 2-theta (data as collected).

Example 23

Methanol Solvate of Modafinil

The methanol solvate of modafinil is obtained by evaporating 2 mL of a 30 mg/mL modafinil solution in methanol under flowing nitrogen overnight. The methanol solvate was characterized by PXRD, TGA, and DSC (See Figures 42, 43, and 44, respectively). The modafinil methanol solvate can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 42 including, but not limited to, 6.15, 9.89, 12.25, 15.69, 17.97, 20.07, 21.85, and 22.73 degrees 2-theta (data as collected).

Example 24

Nitromethane Solvate of Modafinil

The nitromethane solvate of modafinil was prepared by placing 12.9 mg of modafinil in 1 mL of nitromethane. The powder submerged in the nitromethane did not completely dissolve and was observed to coarsen, overnight, forming large rectangular crystals. The solid was collected and analyzed by PXRD (See Figure 45). The modafinil nitromethane solvate can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 45 including, but not limited to, 6.17, 9.77, 15.89, 18.11, 20.07, 22.17, 22.91, 25.31, and 25.83 degrees 2-theta (data as collected).

Example 25

Acetone Solvate of Modafinil

Equimolar amounts of modafinil (30 mg, 0.0001 mol) and glutaric acid were placed in a stainless steel vial. 20 microliters of acetone was added to the vial. The vial was then placed in a grinder (wig-l-bug, Bratt Technologies, 115V/60Hz) and the solid mixture was milled for 5 minutes. The resultant powder was then collected and characterized using PXRD (See Figure 46). The resulting material was characterized as an acetone solvate of modafinil. The acetone solvate of modafinil can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 46 including, but not limited to, 6.11, 9.53, 15.81, 18.11, 20.03, 21.63, 22.45, 25.23, 25.65, 28.85, 30.23, and 32.93 degrees 2-theta (as collected). The acetone solvate may also be obtained following the procedure above with several other co-crystal formers including adipic acid, lactobionic acid, maleic acid, and glycolic acid.

Example 26

Modafinil (1 mg, 0.0037mmol) and mandelic acid (0.55 mg, 0.0037 mmol) were dissolved in acetone (400 microliters). The solution was allowed to evaporate to dryness and the resulting solid was characterized using PXRD (See Figure 47). The obtained solid may be a solvate of modafinil. The form can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 47 including, but not limited to, 6.11, 9.53, 14.77, 15.77, 18.03, 20.01, and 21.61 degrees 2-theta (background removed).

Example 27

Modafinil (1 mg, 0.0037mmol) and fumaric acid (0.42 mg, 0.0037 mmol) were dissolved in 1,2-dichloroethane (400 microliters). The solution was allowed to evaporate to dryness and the resulting solid was characterized using PXRD (See Figure 48). The obtained solid may be a solvate of modafinil. The form can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 48 including, but not limited to, 5.87, 8.95, 12.49, 13.99, 18.19, 19.99, 21.57, and 25.01 degrees 2-theta (background removed).

Example 28

Polymorph of Modafinil

Modafinil was dispensed from a stock solution containing 50 mg of modafinil in 20 mL of a 15:5 acetone/methanol mixture. The solution was then evaporated to dryness under a flow of nitrogen. Mandelic acid was dispensed from an acetone solution and the mixture was again evaporated to dryness. 200 microliters of acetone was then added and the vials were capped. After standing at room temperature for one day, the caps were removed and the solvent was allowed to evaporate. PXRD was carried out on the sample (See Figure 49). The modafinil polymorph is denoted as form VII. The polymorph (form VII) can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 49 including, but not limited to, 5.47, 9.99, 15.73, 17.85, 18.77, 20.05, 21.23, 22.05, 23.15, and 25.13 degrees 2-theta (data as collected).

Example 29

Modafinil:Malonic acid Co-Crystal Pharmacokinetic Study in Dogs

The modafinil:malonic acid co-crystal (from Example 1) was administered to dogs in a pharmacokinetic study. Particles of modafinil:malonic acid co-crystal with a median particle size of about 16 micrometers were administered in the study. As a reference, micronized modafinil with a median particle size of about 2 micrometers was also administered in the study. The AUC of the modafinil:malonic acid co-crystal was

determined to be 40 to 60 percent higher than that of the pure modafinil. Such a higher bioavailability illustrates the modulation of an important pharmacokinetic parameter due to an embodiment of the present invention. A compilation of important pharmacokinetic parameters measured during the animal study are included in Table V.

Table V- Pharmacokinetic parameters of modafinil:malonic acid co-crystal and pure modafinil in dogs

Parameter	**Pure Modafinil**	**Modafinil:malonic acid co-crystal**
Median particle size	2 micrometers	16 micrometers
C_{max} (ng/mL)	11.0 ± 5.9	10.3 ± 3.4
T_{max} (hours)	1.3 ± 0.6	1.7 ± 0.6
AUC (relative)	1.0	1.4-1.6
Half-life (hours)	2.1 ± 0.7	5.1 ± 2.4

The increased half-life and bioavailability of modafinil in the malonic acid co-crystal may be due to the presence of malonic acid. It is believed that the malonic acid may be inhibiting one or more pathways responsible for the metabolism or elimination of modafinil. It is noted that modafinil and malonic acid share a similar structure: each including two carbonyl or sulfonyl groups separated by a $-CH_2-$ and each molecule is terminated with a group that is capable of participation in a hydrogen bond with an enzyme. Such a mechanism may take place with other APIs or co-crystal formers of similar structure.

Example 30

Modafinil:Malonic acid Co-crystal Solid-State Stability

The stability of the modafinil:malonic acid co-crystal was measured at various temperatures and relative humidities over a four week period. No degradation was found to occur at 20 or 40 degrees C. At 60 degrees C, about 0.14 percent degradation per day was determined based on a simple exponential model. At 80 degrees C, about 8 percent degradation per day was determined.

The stability of the modafinil:malonic acid co-crystal was also measured at various temperatures and relative humidities over a 26 week period. Figures 50 and 51 show the % area impurities as measured via HPLC versus time (weeks) for samples stored at various conditions including: 25 degrees C, 60 % RH; 40 degrees C, 75 percent

RH; 40 degrees C, ambient RH; 60 degrees C, ambient RH; 80 degrees C, ambient RH; and –20 degrees C. These data show that the compound is stable when stored at or below 40 degrees C for at least 26 weeks. Figure 52 compares PXRD patterns of initial and 26 week old samples of the modafinil:malonic acid co-crystal for several temperatures and RH levels.

Example 31

Formulation of Modafinil:Malonic Acid Co-crystal

The formulation of a modafinil:malonic acid co-crystal was completed using lactose. Two mixtures, one of modafinil and lactose, and the second of modafinil:malonic acid co-crystal and lactose, were ground together in a mortar an pestle. The mixtures targeted a 1:1 weight ratio of modafinil to lactose. In the modafinil and lactose mixture, 901.2 mg of modafinil and 901.6 mg of lactose were ground together. In the modafinil:malonic acid co-crystal and lactose mixture, 1221.6 mg of co-crystal and 871.4 mg of lactose were ground together. The resulting powders were analyzed by PXRD and DSC. The PXRD patterns and DSC thermograms of the mixtures showed virtually no change upon comparison with both individual components. The DSC of the co-crystal mixture showed only the co-crystal melting peak at 113.6 degrees C with a heat of fusion of 75.9 J/g. This heat of fusion is 59.5 % of that found for the co-crystal alone (127.5 J/g). This result is consistent with a 58.4 % weight ratio of co-crystal in the mixture. The DSC of the modafinil and lactose mixture had a melting point of 165.7 degrees C. This is slightly lower then the measured melting point of modafinil (168.7 degrees C). The heat of fusion of the mixture (59.3 J/g) is 46.9 % that of the modafinil alone (126.6 J/g), which is consistent with the estimated value of 50 %.

The *in vitro* dissolution of both the modafinil:malonic acid co-crystal and pure modafinil were tested in capsules. Both gelatin and hydroxypropylmethyl cellulose (HPMC) capsules were used in the dissolution study. The capsules were formulated with and without lactose. All formulations were ground in a mortar and pestle prior to transfer into a capsule. The dissolution of the capsules was tested in 0.01 M HCl (See Figure 53).

In 0.01N HCl, using sieved and ground materials in gelatin capsules:

Modafinil and the modafinil:malonic acid co-crystal were passed through a 38 micrometer sieve. Gelatin capsules (Size 0, B&B Pharmaceuticals, Lot # 15-01202) were filled with 200.0 mg sieved modafinil, 280.4 mg sieved modafinil:malonic acid co-crystal, 200.2 mg ground modafinil, or 280.3 mg ground modafinil:malonic acid co-crystal. Dissolution studies were performed in a Vankel VK 7000 Benchsaver Dissolution Testing Apparatus with the VK750D heater/circulator set at 37 degrees C. At 0 minutes, the capsules were dropped into vessels containing 900 mL 0.01 M HCl and stirred by paddles.

Absorbance readings were taken using a Cary 50 Spectrophotometer (wavelength set at 260nm) at the following time points: 0, 5, 10, 15, 20, 25, 30, 40, 50, and 60 minutes. The absorbance values were compared to those of standards and the modafinil concentrations of the solutions were calculated.

In 0.01N HCl, using ground materials in gelatin or HPMC capsules, with and without lactose:

Modafinil and the modafinil:malonic acid co-crystal were mixed with equivalent amounts of lactose (Spectrum, Lot QV0460) for approximately 5 minutes. Gelatin capsules (Size 0, B&B Pharmaceuticals, Lot # 15-01202) were filled with 400.2 mg modafinil and lactose (approximately 200 mg modafinil), or 561.0 mg modafinil:malonic acid co-crystal and lactose (approximately 200 mg modafinil). HPMC capsules (Size 0, Shionogi, Lot # A312A6) were filled with 399.9 mg modafinil and lactose, 560.9 mg modafinil:malonic acid co-crystal and lactose, 199.9 mg modafinil, or 280.5 mg modafinil:malonic acid co-crystal. The dissolution study was carried out as described above.

Example 32

In Vitro Dissolution

Figure 54 shows in vitro dissolution data of micronized modafinil:malonic acid co-crystal and of micronized modafinil in simulated gastric fluid (SGF) and in simulated intestinal fluid (SIF). Both samples were blended with lactose and filled into HPMC capsules. The co-crystal releases modafinil into solution more quickly in both SGF and SIF than does the free form of modafinil. Figure 55 compares the dissolution of an

HPMC capsule filled with the modafinil:malonic acid co-crystal blended with lactose and that of a PROVIGIL tablet. Figure 56 shows a dynamic vapor sorption (DVS) isotherm plot of the modafinil:malonic acid co-crystal. This plot shows no appreciable water adsorption up to at least 40 percent RH at 26 degrees C.

Example 33

In Vivo Studies

A pharmacokinetic study was completed with dogs using both modafinil:malonic acid formulated with lactose and PROVIGIL tablets (200 mg). Seven capsules were filled with the modafinil:malonic acid co-crystal and lactose to 476.24 +/- 2 mg, each containing 200 mg modafinil. Figure 57 shows the co-crystal formulation has an increased C_{max} and an increased bioavailability. Severel important pharmacokinetic parameters are described in Table VI.

Table VI- PK parameters of modafinil:malonic acid co-crystal and PROVIGIL from In Vivo study

PROVIGIL (200 mg)						
Animal	**Cmax**	**AUC (inf)**	**$t_{1/2}$**	**Tmax**	**CL**	**F %**
Mean	7838.33	41193.33	1.76	2.00	524.17	66.48
SD	2734.35	8104.32	0.88	0.63	146.98	13.08
% CV	34.9	19.7	49.7	31.6	28.0	19.7
Modafinil:malonic acid (200 mg modafinil)						
Animal	**Cmax**	**AUC (inf)**	**$t_{1/2}$**	**Tmax**	**CL**	**F %**
Mean	11246.67	50545.00	1.63	2.00	368.33	81.57
SD	1662.13	10635.46	0.64	0.89	165.60	17.16
% CV	14.8	21.0	39.5	44.7	45.0	21.0

Example 34

Polymorphs of R-(-)-modafinil

Five polymorphs of R-(-)-modafinil have been observed, each characterized by PXRD. Figures 58, 59, 60, and 61 shows these PXRD diffractograms (data as collected) of polymorphs Form I, Form II, Form III, Form IV, and Form V respectively. R-(-)-modafinil Forms I and II were crystallized from ethanol via thermal recrystallization or via evaporation of the solvent. R-(-)-modafinil Form III was crystallized from a mixture of ethanol and isopropyl alcohol via thermal recrystallization or via evaporation of the

solvent. R-(-)-modafinil Forms IV and V were crystallized from mixtures of ethyl acetate and ethanol via thermal recrystallization or via evaporation of the solvent. A polymorphic mixture of forms I and II is characterized in Figure 58 and has a melting point of about 166.8 degrees C as determined by DSC. The mixture of Forms I and II can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 58 including, but not limited to, 8.97, 10.15, 12.87, 14.15, 15.13, 15.77, 18.18, and 20.39 degrees 2-theta (data as collected). R-(-)-modafinil form I can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 58 including, but not limited to, 8.97, 10.15, 12.87, 15.13, 15.77, 18.19, and 19.25 degrees 2-theta (data as collected). R-(-)-modafinil form II can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 58 including, but not limited to, 8.97, 10.15, 14.15, 15.13, 17.41, and 18.19 degrees 2-theta (data as collected). The polymorph form III characterized in Figure 59 has a melting point of about 161.0 degrees C as determined by DSC. Form III can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 59 including, but not limited to, 7.21, 10.37, 17.73, 19.23, 21.17, 21.77 and 23.21 degrees 2-theta (data as collected). Form V can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 60 including, but not limited to, 6.61, 10.39, 13.99, 16.49, 17.73, 19.03, 20.87 and 22.31 degrees 2-theta (data as collected). The polymorph form IV characterized in Figure 61 has a melting point of about 147.3 degrees C as determined by DSC. Form IV can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 61 including, but not limited to, 7.79, 10.31, 11.77, 16.49, 17.33, 19.47, and 23.51 degrees 2-theta (data as collected). The polymorphs of R-(-)-modafinil are named Forms I, II, III, IV, and V based on similarities in the PXRD diffractograms to those found in the diffractograms for corresponding racemic modafinil Forms I, II, III, IV, and V in US Patent Application No. 20020043207, published on April 18, 2002.

Example 35

R-(-)-modafinil:Gentisic acid Co-crystal

Equimolar amounts of R-(-)-modafinil (30 mg, 0.0001 mol) and gentisic acid were placed in a stainless steel vial. 20 microliters of acetone was added to the vial. The vial was then placed in a grinder (wig-l-bug, Bratt Technologies, 115V/60Hz) and the solid mixture was milled for 5 minutes. The resultant powder was then collected and characterized using PXRD (See Figure 62). The R-(-)-modafinil:gentisic acid co-crystal can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 62 including, but not limited to, 7.07, 7.51, 9.07, 12.31, 16.03, 17.63, 18.39, 19.83, 21.27, 23.57, 26.93, and 28.85 degrees 2-theta (as collected).

Example 36

Channel Solvates of Modafinil

Channel solvates of modafinil have been unexpectedly discovered. Equimolar amounts of modafinil (30 mg, 0.0001 mol) and 1-hydroxy-2-naphthoic acid were placed in a stainless steel vial. 20 microliters of acetone was added to the vial. The vial was then placed in a grinder (wig-l-bug, Bratt Technologies, 115V/60Hz) and the solid mixture was milled for 5 minutes. The resultant powder was then collected and characterized. The resulting material was characterized as an acetone channel solvate of modafinil. Single-crystal x-ray parameters: P2(1)/n, a = 12.737(3) angstroms, b = 5.5945(11) angstroms, c = 22.392(5) angstroms, alpha= 90 degrees, beta= 104.140(4) degrees, gamma = 90 degrees, V = 1547.3(5) cubic angstroms, Z = 2. Figures 63 and 64 show packing diagrams of the acetone channel solvate of modafinil. The packing diagrams show acetone with a variable position within the channel structure. An ethyl acetate channel solvate has also been prepared according to the method above using ethyl acetate in place of acetone.

Example 37

o-Xylene Hemisolvate

An *o*-xylene hemisolvate was formed by preparing a 1:2 solution of modafinil (49.6 mg, 0.181 mmol) and 1-hydroxy-2-napthoic acid (68.3 mg, 0.363 mmol) in *o*-

xylene (4.5 mL). The mixture was heated on a hotplate with swirling until all solids were dissolved. The solution was then left to crystallize in a sealed vial. The resulting powder was collected in a centrifuge filter and analyzed by PXRD (Figure 65), Raman spectroscopy (Figure 66), TGA(Figure 67), and DSC (Figure 68). The *o*-xylene solvate can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 65 including, but not limited to, 5.31, 6.53, 6.96, 10.68, 14.20, 17.64, 19.93, 25.69, and 26.79 degrees 2-theta. The *o*-xylene solvate can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 66 (middle spectrum) including, but not limited to, 1641, 1407, 1379, 1211, 1024, and 721 cm^{-1}.

Example 38

Benzene Hemisolvate

A benzene hemisolvate was formed by preparing a 1:2 solution of modafinil (50.6 mg, 0.181 mmol) and 1-hydroxy-2-napthoic acid (70.1 mg, 0.373 mmol) in benzene (1.8 mL). The mixture was heated on a hotplate with swirling until all solids were dissolved. The solution was then left to crystallize in a sealed vial. The resulting powder was collected in a centrifuge filter and analyzed by PXRD (Figure 69), Raman spectroscopy (Figure 70), TGA (Figure 71), and DSC (Figure 72). The benzene solvate can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 69 including, but not limited to, 5.82, 6.09, 8.11, 10.28, 12.06, 13.28, 14.73, 17.03, 19.11, 19.93, 21.23, 25.38, and 26.43 degrees 2-theta. The benzene solvate can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 70 (middle spectrum) including, but not limited to, 1637, 1600, 1409, 1380, 1214, 1025, 998, and 721 cm^{-1}.

Example 39

Toluene Hemisolvate

A toluene hemisolvate was formed by making a 1:2 solution of modafinil (37.3 mg, 0.136 mmol) and 1-hydroxy-2-napthoic acid (51.3 mg, 0.273 mmol) in toluene (1 mL). The mixture was heated on a hotplate with swirling until all solids were dissolved.

The solution was then left to crystallize in a sealed vial. The resulting powder was collected in a centrifuge filter and analyzed by PXRD (Figure 73), Raman spectroscopy (Figure 74), TGA (Figure 75), and DSC (Figure 76). The toluene solvate can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 73 including, but not limited to, 5.30, 5.96, 10.65, 12.90, 14.51, 17.60, and 18.15 degrees 2-theta. The toluene solvate can be characterized by any one, any two, any three, any four, any five, or any six or more of the peaks in Figure 74 (middle spectrum) including, but not limited to, 1640, 1581, 1408, 1380, 1209, 1024, 1001, and 722 cm^{-1}.

What is claimed is:

1. A pharmaceutical co-crystal composition, comprising: modafinil and a co-crystal former, wherein the co-crystal former is a solid at room temperature, and wherein the modafinil and the co-crystal former are hydrogen bonded to each other.

2. The pharmaceutical co-crystal composition according to claim 1, wherein:

(a) the co-crystal former is selected from a co-crystal former of Table I or Table II;

(b) the co-crystal former has at least one functional group selected from the group consisting of ether, thioether, alcohol, thiol, aldehyde, ketone, thioketone, nitrate ester, phosphate ester, thiophosphate ester, ester, thioester, sulfate ester, carboxylic acid, phosphonic acid, phosphinic acid, sulfonic acid, amide, primary amine, secondary amine, ammonia, tertiary amine, sp2 amine, thiocyanate, cyanamide, oxime, nitrile diazo, organohalide, nitro, S-heterocyclic ring, thiophene, N-heterocyclic ring, pyrrole, O-heterocyclic ring, furan, epoxide, peroxide, hydroxamic acid, imidazole, and pyridine;

(c) the solubility of the co-crystal is increased as compared to the modafinil;

(d) the dose response of the co-crystal is increased as compared to the modafinil;

(e) the dissolution of the co-crystal is increased as compared to the modafinil;

(f) the bioavailability of the co-crystal is increased as compared to the modafinil; or

(g) the stability of the co-crystal is increased as compared to the modafinil.

3. A pharmaceutical co-crystal composition, comprising: modafinil, a co-crystal former, and a third molecule; wherein the co-crystal former is a solid at room temperature,

and wherein the modafinil and the third molecule are bonded to each other, and further wherein the co-crystal former and the third molecule are hydrogen bonded to each other.

4. The pharmaceutical co-crystal composition according to claim 3, wherein:

(a) the co-crystal former is selected from a co-crystal former of Table I or Table II;

(b) the co-crystal former has at least one functional group selected from the group consisting of ether, thioether, alcohol, thiol, aldehyde, ketone, thioketone, nitrate ester, phosphate ester, thiophosphate ester, ester, thioester, sulfate ester, carboxylic acid, phosphonic acid, phosphinic acid, sulfonic acid, amide, primary amine, secondary amine, ammonia, tertiary amine, sp2 amine, thiocyanate, cyanamide, oxime, nitrile diazo, organohalide, nitro, S-heterocyclic ring, thiophene, N-heterocyclic ring, pyrrole, O-heterocyclic ring, furan, epoxide, peroxide, hydroxamic acid, imidazole, and pyridine; or

(c) the solubility of the co-crystal is increased as compared to the modafinil;

(d) the dose response of the co-crystal is increased as compared to the modafinil;

(e) the dissolution of the co-crystal is increased as compared to the modafinil;

(f) the bioavailability of the co-crystal is increased as compared to the modafinil; or

(g) the stability of the co-crystal is increased as compared to the modafinil.

5. A pharmaceutical co-crystal composition, comprising: modafinil and a second API, wherein the second API is either a liquid or a solid at room temperature, and wherein the modafinil and the second API are hydrogen bonded to a molecule.

6. The pharmaceutical co-crystal composition according to claim 5, wherein:

(a) the modafinil is hydrogen bonded to the second API;

(b) the second API is a liquid at room temperature;

(c) the second API is a solid at room temperature;

(d) the second API has at least one functional group selected from the group consisting of ether, thioether, alcohol, thiol, aldehyde, ketone, thioketone, nitrate ester, phosphate ester, thiophosphate ester, ester, thioester, sulfate ester, carboxylic acid, phosphonic acid, phosphinic acid, sulfonic acid, amide, primary amine, secondary amine, ammonia, tertiary amine, sp2 amine, thiocyanate, cyanamide, oxime, nitrile, diazo, organohalide, nitro, S-heterocyclic ring, thiophene, N-heterocyclic ring, pyrrole, O-heterocyclic ring, furan, epoxide, peroxide, hydroxamic acid, imidazole, and pyridine;

(e) the solubility of the co-crystal is increased as compared to the modafinil;

(f) the dose response of the co-crystal is increased as compared to the modafinil;

(g) the dissolution of the co-crystal is increased as compared to the modafinil;

(h) the bioavailability of the co-crystal is increased as compared to the modafinil; or

(i) the stabilit y of the co-crystal is increased as compared to the modafinil.

7. The pharmaceutical co-crystal composition according to claim 1, further comprising a pharmaceutically acceptable diluent, excipient, or carrier.

8. A co-crystal comprising modafinil and a co-crystal former selected from the group consisting of: malonic acid, glycolic acid, fumaric acid, tartaric acid, citric acid, succinic acid, gentisic acid, oxalic acid, 1-hydroxy-2-naphthoic acid, lauric acid, orotic acid, and maleic acid.

9. The co-crystal according to claim 8, wherein:

(a) the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(i) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.11, 9.35, and 16.87 degrees;

(ii) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises peaks at 16.87, 18.33, and 19.53 degrees;

(iii) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises peaks at 9.35, 19.53, and 22.89 degrees;

(iv) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.11 and 9.35 degrees;

(v) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises peaks at 16.87 and 19.53 degrees;

(vi) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises peaks at 18.33 and 22.89 degrees;

(vii) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises a peak at 5.11 degrees;

(viii) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises a peak at 9.35 degrees; or

(ix) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises a peak at 16.87 degrees;

(b) the co-crystal is characterized by a DSC thermogram, wherein said co-crystal is a modafinil:malonic acid co-crystal and said DSC thermogram comprises an endothermic transition at about 106 degrees C; or

(c) the co-crystal is characterized by a Raman spectrum comprising peaks expressed in terms of cm^{-1}, wherein:

(i) said co-crystal is a modafinil:malonic acid co-crystal and said Raman spectrum comprises peaks at 1004, 633, and 265;

(ii) said co-crystal is a modafinil:malonic acid co-crystal and said Raman spectrum comprises peaks at 1032, 1601, and 767;

(iii) said co-crystal is a modafinil:malonic acid co-crystal and said Raman spectrum comprises peaks at 1004 and 633;

(iv) said co-crystal is a modafinil:malonic acid co-crystal and said Raman spectrum comprises peaks at 1183 and 767; or

(v) said co-crystal is a modafinil:malonic acid co-crystal and said Raman spectrum comprises peaks at 1601 and 718.

10. The co-crystal according to claim 8, wherein the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said co-crystal is a modafinil:glycolic acid co-crystal and said X-ray diffraction pattern comprises peaks at 9.51, 15.97, and 20.03 degrees;

(b) said co-crystal is a modafinil:glycolic acid co-crystal and said X-ray diffraction pattern comprises peaks at 14.91, 19.01, and 22.75 degrees;

(c) said co-crystal is a modafinil:glycolic acid co-crystal and said X-ray diffraction pattern comprises peaks at 15.97, 25.03, and 25.71 degrees;

(d) said co-crystal is a modafinil:glycolic acid co-crystal and said X-ray diffraction pattern comprises peaks at 9.51 and 15.97 degrees;

(e) said co-crystal is a modafinil:glycolic acid co-crystal and said X-ray diffraction pattern comprises peaks at 20.03 and 25.03 degrees;

(f) said co-crystal is a modafinil:glycolic acid co-crystal and said X-ray diffraction pattern comprises peaks at 15.97 and 25.03 degrees;

(g) said co-crystal is a modafinil:glycolic acid co-crystal and said X-ray diffraction pattern comprises a peak at 9.51 degrees;

(h) said co-crystal is a modafinil:glycolic acid co-crystal and said X-ray diffraction pattern comprises a peak at 15.97 degrees; or

(i) said co-crystal is a modafinil:glycolic acid co-crystal and said X-ray diffraction pattern comprises a peak at 20.03 degrees.

11. The co-crystal according to claim 8, wherein:

(a) the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(i) said co-crystal is a modafinil:maleic acid co-crystal and said X-ray diffraction pattern comprises peaks at 4.69, 6.15, and 9.61 degrees;

(ii) said co-crystal is a modafinil:maleic acid co-crystal and said X-ray diffraction pattern comprises peaks at 10.23, 19.97, and 21.83 degrees;

(iii) said co-crystal is a modafinil:maleic acid co-crystal and said X-ray diffraction pattern comprises peaks at 4.69, 10.23, and 21.83 degrees;

(iv) said co-crystal is a modafinil:maleic acid co-crystal and said X-ray diffraction pattern comprises peaks at 4.69 and 19.97 degrees;

(v) said co-crystal is a modafinil:maleic acid co-crystal and said X-ray diffraction pattern comprises peaks at 6.15 and 9.61 degrees;

(vi) said co-crystal is a modafinil:maleic acid co-crystal and said X-ray diffraction pattern comprises peaks at 4.69 and 6.15 degrees;

(vii) said co-crystal is a modafinil:maleic acid co-crystal and said X-ray diffraction pattern comprises a peak at 4.69 degrees;

(viii) said co-crystal is a modafinil:maleic acid co-crystal and said X-ray diffraction pattern comprises a peak at 9.61 degrees; or

(x) said co-crystal is a modafinil:maleic acid co-crystal and said X-ray diffraction pattern comprises a peak at 19.97 degrees; or

(b) the co-crystal is characterized by a DSC thermogram, wherein said co-crystal is a modafinil:maleic acid co-crystal and said DSC thermogram comprises an endothermic transition at about 168 degrees C.

12. The co-crystal according to claim 8, wherein the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said co-crystal is a modafinil:L-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 6.10, 14.33, and 20.71 degrees;

(b) said co-crystal is a modafinil:L-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 16.93, 20.15, and 22.49 degrees;

(c) said co-crystal is a modafinil:L-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 16.93, 20.71, and 29.72 degrees;

(d) said co-crystal is a modafinil:L-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 6.10 and 20.15 degrees;

(e) said co-crystal is a modafinil:L-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 14.33 and 20.71 degrees;

(f) said co-crystal is a modafinil:L-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 7.36 and 25.04 degrees;

(g) said co-crystal is a modafinil:L-tartaric acid co-crystal and said X-ray diffraction pattern comprises a peak at 6.10 degrees;

(h) said co-crystal is a modafinil:L-tartaric acid co-crystal and said X-ray diffraction pattern comprises a peak at 16.93 degrees; or

(i) said co-crystal is a modafinil:L-tartaric acid co-crystal and said X-ray diffraction pattern comprises a peak at 20.71 degrees.

13. The co-crystal according to claim 8, wherein the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.29, 7.29, and 9.31 degrees;

(b) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises peaks at 12.41, 13.29, and 14.61 degrees;

(c) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises peaks at 17.29, 17.97, and 21.37 degrees;

(d) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.29 and 17.29 degrees;

(e) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises peaks at 7.29 and 9.31 degrees;

(f) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises peaks at 12.41 and 21.37 degrees;

(g) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises a peak at 5.29 degrees;

(h) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises a peak at 7.29 degrees; or

(i) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises a peak at 12.41 degrees.

14. The co-crystal according to claim 8, wherein:

(a) the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(i) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.45, 9.93, and 17.99 degrees;

(ii) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises peaks at 19.95, 21.95, and 25.07 degrees;

(iii) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.45, 17.99, and 21.35 degrees;

(iv) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.45 and 9.93 degrees;

(v) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises peaks at 17.99 and 21.95 degrees;

(vi) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises peaks at 9.93 and 19.95 degrees;

(vii) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises a peak at 5.45 degrees;

(viii) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises a peak at 9.93 degrees; or

(xi) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises a peak at 17.99 degrees; or

(b) the co-crystal is characterized by a DSC thermogram, wherein said co-crystal is a modafinil:succinic acid co-crystal and said DSC thermogram comprises an endothermic transition at about 149 degrees C.

15. The co-crystal according to claim 8, wherein the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 4.75, 9.53, and 15.83 degrees;

(b) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 17.61, 20.25, and 22.55 degrees;

(c) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 10.07, 17.61, and 21.53 degrees;

(d) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 4.75 and 15.83 degrees;

(e) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 9.53 and 17.61 degrees;

(f) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 21.53 and 22.55 degrees;

(g) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises a peak at 4.75 degrees;

(h) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises a peak at 9.53 degrees; or

(i) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises a peak at 15.83 degrees.

16. The co-crystal according to claim 8, wherein the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.45, 9.95, and 18.03 degrees;

(b) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 15.93, 18.81, and 21.95 degrees;

(c) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 9.95, 19.93, and 23.09 degrees;

(d) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.45 and 9.95 degrees;

(e) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.45 and 18.03 degrees;

(f) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 15.93 and 21.95 degrees;

(g) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises a peak at 5.45 degrees;

(h) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises a peak at 9.95 degrees; or

(i) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises a peak at 18.03 degrees.

17. The co-crystal according to claim 16, wherein the co-crystal is modafinil:fumaric acid Form I.

18. The co-crystal according to claim 8, wherein the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 6.47, 8.57, and 9.99 degrees;

(b) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 13.89, 14.53, and 20.79 degrees;

(c) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 16.45, 18.39, and 20.05 degrees;

(d) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 6.47 and 20.79 degrees;

(e) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 9.99 and 14.53 degrees;

(f) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 13.89 and 20.05 degrees;

(g) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises a peak at 6.47 degrees;

(h) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises a peak at 13.89 degrees; or

(i) said co-crystal is a modafinil:fumaric acid co-crystal and said X-ray diffraction pattern comprises a peak at 20.79 degrees.

19. The co-crystal according to claim 18, wherein the co-crystal is modafinil:fumaric acid Form II.

20. The co-crystal according to claim 8, wherein the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said co-crystal is a modafinil:gentisic acid co-crystal and said X-ray diffraction pattern comprises peaks at 6.96, 12.92, and 14.76 degrees;

(b) said co-crystal is a modafinil:gentisic acid co-crystal and said X-ray diffraction pattern comprises peaks at 14.76, 18.26, and 20.10 degrees;

(c) said co-crystal is a modafinil:gentisic acid co-crystal and said X-ray diffraction pattern comprises peaks at 6.96, 17.40, and 20.94 degrees;

(d) said co-crystal is a modafinil:gentisic acid co-crystal and said X-ray diffraction pattern comprises peaks at 6.96 and 14.76 degrees;

(e) said co-crystal is a modafinil:gentisic acid co-crystal and said X-ray diffraction pattern comprises peaks at 12.92 and 17.40 degrees;

(f) said co-crystal is a modafinil:gentisic acid co-crystal and said X-ray diffraction pattern comprises peaks at 6.96 and 18.26 degrees;

(g) said co-crystal is a modafinil:gentisic acid co-crystal and said X-ray diffraction pattern comprises a peak at 6.96 degrees;

(h) said co-crystal is a modafinil:gentisic acid co-crystal and said X-ray diffraction pattern comprises a peak at 14.76 degrees; or

(i) said co-crystal is a modafinil:gentisic acid co-crystal and said X-ray diffraction pattern comprises a peak at 18.26 degrees.

21. The co-crystal according to claim 8, wherein the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said co-crystal is a modafinil:oxalic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.98, 17.54, and 19.68 degrees;

(b) said co-crystal is a modafinil:oxalic acid co-crystal and said X-ray diffraction pattern comprises peaks at 13.68, 14.80, and 21.12 degrees;

(c) said co-crystal is a modafinil:oxalic acid co-crystal and said X-ray diffraction pattern comprises peaks at 17.54, 19.68, and 21.86 degrees;

(d) said co-crystal is a modafinil:oxalic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.98 and 19.68 degrees;

(e) said co-crystal is a modafinil:oxalic acid co-crystal and said X-ray diffraction pattern comprises peaks at 13.68 and 14.80 degrees;

(f) said co-crystal is a modafinil:oxalic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.98 and 17.54 degrees;

(g) said co-crystal is a modafinil:oxalic acid co-crystal and said X-ray diffraction pattern comprises a peak at 5.98 degrees;

(h) said co-crystal is a modafinil:oxalic acid co-crystal and said X-ray diffraction pattern comprises a peak at 19.68 degrees; or

(i) said co-crystal is a modafinil:oxalic acid co-crystal and said X-ray diffraction pattern comprises a peak at 17.54 degrees.

22. The co-crystal according to claim 8, wherein the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.72, 7.10, and 14.16 degrees;

(b) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises peaks at 11.48, 15.66, and 20.26 degrees;

(c) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.72, 7.10, and 20.26 degrees;

(d) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.72 and 7.10 degrees;

(e) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises peaks at 14.16 and 20.26 degrees;

(f) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.72 and 14.16 degrees;

(g) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises a peak at 5.72 degrees;

(h) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises a peak at 7.10 degrees; or

(i) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises a peak at 14.16 degrees.

23. The co-crystal according to claim 8, wherein:

(a) the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(i) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.04, 9.26, and 16.73 degrees;

(ii) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises peaks at 18.23, 19.37, and 22.74 degrees;

(iii) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.04, 16.73, and 19.37 degrees;

(iv) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.04 and 9.26 degrees;

(v) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises peaks at 16.73 and 19.37 degrees;

(vi) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises peaks at 9.26 and 18.23 degrees;

(vii) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises a peak at 5.04 degrees;

(viii) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises a peak at 9.26 degrees; or

(ix) said co-crystal is a modafinil:malonic acid co-crystal and said X-ray diffraction pattern comprises a peak at 19.37 degrees; or

(b) the co-crystal is characterized by a DSC thermogram, wherein said co-crystal is a modafinil:malonic acid co-crystal and said DSC thermogram comprises an endothermic transition at about 115 degrees C.

24. The co-crystal according to claim 23, wherein the modafinil is R-(-)-modafinil.

25. The co-crystal according to claim 8, wherein:

(a) the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(i) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.36, 9.83, and 17.88 degrees;

(ii) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises peaks at 15.80, 19.87, and 21.85 degrees;

(iii) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.36, 9.83, and 21.85 degrees;

(iv) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.36 and 9.83 degrees;

(v) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises peaks at 17.88 and 19.87 degrees;

(vi) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises peaks at 9.83 and 15.80 degrees;

(vii) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises a peak at 5.36 degrees;

(viii) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises a peak at 9.83 degrees; or

(ix) said co-crystal is a modafinil:succinic acid co-crystal and said X-ray diffraction pattern comprises a peak at 17.88 degrees; or

(b) the co-crystal is characterized by a DSC thermogram, wherein said co-crystal is a modafinil:succinic acid co-crystal and said DSC thermogram comprises an endothermic transition at about 145 degrees C.

26. The co-crystal according to claim 25, wherein the modafinil is R-(-)-modafinil.

27. The co-crystal according to claim 8, wherein:

(a) the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(i) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.18, 7.23, and 9.23 degrees;

(ii) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises peaks at 12.32, 13.23, and 17.25 degrees;

(iii) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises peaks at 9.23, 17.92, and 21.30 degrees;

(iv) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.18 and 9.23 degrees;

(v) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises peaks at 7.23 and 13.23 degrees;

(vi) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises peaks at 17.25 and 17.92 degrees;

(vii) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises a peak at 5.18 degrees;

(viii) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises a peak at 7.23 degrees; or

(ix) said co-crystal is a modafinil:citric acid co-crystal and said X-ray diffraction pattern comprises a peak at 9.23 degrees; or

(b) the co-crystal is characterized by a DSC thermogram, wherein said co-crystal is a modafinil:citric acid co-crystal and said DSC thermogram comprises an endothermic transition at about 89 degrees C.

28. The co-crystal according to claim 27, wherein the modafinil is R-(-)-modafinil.

29. The co-crystal according to claim 8, wherein the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.77, 7.11, and 9.09 degrees;

(b) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises peaks at 10.37, 12.23, and 14.81 degrees;

(c) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises peaks at 14.17, 17.09, and 21.39 degrees;

(d) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises peaks at 9.09 and 14.81 degrees;

(e) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises peaks at 5.77 and 10.37 degrees;

(f) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises peaks at 7.11 and 14.17 degrees;

(g) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises a peak at 5.77 degrees;

(h) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises a peak at 9.09 degrees; or

(i) said co-crystal is a modafinil:1-hydroxy-2-naphthoic acid co-crystal and said X-ray diffraction pattern comprises a peak at 14.81 degrees.

30. The co-crystal according to claim 29, wherein the modafinil is R-(-)-modafinil.

31. The co-crystal according to claim 8, wherein the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 4.67, 15.41, and 19.46 degrees;

(b) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 17.97, 19.46, and 22.91 degrees;

(c) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 4.67, 22.91, and 24.63 degrees;

(d) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 4.67 and 19.46 degrees;

(e) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 17.97 and 22.91 degrees;

(f) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises peaks at 15.41 and 24.63 degrees;

(g) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises a peak at 4.67 degrees;

(h) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises a peak at 19.46 degrees; or

(i) said co-crystal is a modafinil:DL-tartaric acid co-crystal and said X-ray diffraction pattern comprises a peak at 22.91 degrees.

32. The co-crystal according to claim 31, wherein the modafinil is R-(-)-modafinil.

33. The co-crystal according to claim 8, wherein the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said co-crystal is a modafinil:lauric acid co-crystal and said X-ray diffraction pattern comprises peaks at 3.15, 7.17, and 10.25 degrees;

(b) said co-crystal is a modafinil:lauric acid co-crystal and said X-ray diffraction pattern comprises peaks at 17.67, 21.43, and 23.84 degrees;

(c) said co-crystal is a modafinil:lauric acid co-crystal and said X-ray diffraction pattern comprises peaks at 3.15, 10.25, and 21.43 degrees;

(d) said co-crystal is a modafinil:lauric acid co-crystal and said X-ray diffraction pattern comprises peaks at 3.15 and 10.25 degrees;

(e) said co-crystal is a modafinil:lauric acid co-crystal and said X-ray diffraction pattern comprises peaks at 17.67 and 21.43 degrees;

(f) said co-crystal is a modafinil:lauric acid co-crystal and said X-ray diffraction pattern comprises peaks at 7.17 and 23.84 degrees;

(g) said co-crystal is a modafinil:lauric acid co-crystal and said X-ray diffraction pattern comprises a peak at 3.15 degrees;

(h) said co-crystal is a modafinil:lauric acid co-crystal and said X-ray diffraction pattern comprises a peak at 10.25 degrees; or

(i) said co-crystal is a modafinil:lauric acid co-crystal and said X-ray diffraction pattern comprises a peak at 21.43 degrees.

34. The co-crystal according to claim 33, wherein the modafinil is R-(-)-modafinil.

35.. The co-crystal according to claim 8, wherein the co-crystal is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said co-crystal is a modafinil:orotic acid co-crystal and said X-ray diffraction pattern comprises peaks at 9.77, 17.85, and 20.52 degrees;

(b) said co-crystal is a modafinil:orotic acid co-crystal and said X-ray diffraction pattern comprises peaks at 14.61, 24.03, and 26.80 degrees;

(c) said co-crystal is a modafinil:orotic acid co-crystal and said X-ray diffraction pattern comprises peaks at 9.77, 20.52, and 24.03 degrees;

(d) said co-crystal is a modafinil:orotic acid co-crystal and said X-ray diffraction pattern comprises peaks at 9.77 and 14.61 degrees;

(e) said co-crystal is a modafinil:orotic acid co-crystal and said X-ray diffraction pattern comprises peaks at 17.85 and 24.03 degrees;

(f) said co-crystal is a modafinil:orotic acid co-crystal and said X-ray diffraction pattern comprises peaks at 14.61 and 26.80 degrees;

(g) said co-crystal is a modafinil:orotic acid co-crystal and said X-ray diffraction pattern comprises a peak at 9.77 degrees;

(h) said co-crystal is a modafinil:orotic acid co-crystal and said X-ray diffraction pattern comprises a peak at 17.85 degrees; or

(i) said co-crystal is a modafinil:orotic acid co-crystal and said X-ray diffraction pattern comprises a peak at 24.03 degrees.

36. The co-crystal according to claim 35, wherein the modafinil is R-(-)-modafinil.

37. A pharmaceutical composition wherein the composition is a solvate form and is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said form is a modafinil acetic acid solvate and said X-ray diffraction pattern comprises peaks at 6.17, 9.63, and 19.99 degrees;

(b) said form is a modafinil acetic acid solvate and said X-ray diffraction pattern comprises peaks at 6.17 and 9.63 degrees;

(c) said form is a modafinil acetic acid solvate and said X-ray diffraction pattern comprises peaks at 19.99 and 21.83 degrees;

(d) said form is a modafinil acetic acid solvate and said X-ray diffraction pattern comprises peaks at 9.63 and 19.99 degrees; or

(e) said form is a modafinil acetic acid solvate and said X-ray diffraction pattern comprises a peak at 6.17 degrees.

38. A pharmaceutical composition wherein the composition is a solvate form and is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said form is a modafinil tetrahydrofuran solvate and said X-ray diffraction pattern comprises peaks at 6.97, 9.79, and 10.97 degrees;

(b) said form is a modafinil tetrahydrofuran solvate and said X-ray diffraction pattern comprises peaks at 10.97 and 20.59 degrees;

(c) said form is a modafinil tetrahydrofuran solvate and said X-ray diffraction pattern comprises peaks at 9.79 and 19.03 degrees;

(d) said form is a modafinil tetrahydrofuran solvate and said X-ray diffraction pattern comprises peaks at 6.97 and 16.19 degrees; or

(e) said form is a modafinil tetrahydrofuran solvate and said X-ray diffraction pattern comprises a peak at 6.97 degrees.

39. A pharmaceutical composition wherein the composition is a solvate form and is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said form is a modafinil 1,4-dioxane solvate and said X-ray diffraction pattern comprises peaks at 6.93, 9.85, and 10.97 degrees;

(b) said form is a modafinil 1,4-dioxane solvate and said X-ray diffraction pattern comprises peaks at 6.93 and 20.65 degrees;

(c) said form is a modafinil 1,4-dioxane solvate and said X-ray diffraction pattern comprises peaks at 10.97 and 18.97 degrees;

(d) said form is a modafinil 1,4-dioxane solvate and said X-ray diffraction pattern comprises peaks at 16.19 and 23.33 degrees; or

(e) said form is a modafinil 1,4-dioxane solvate and said X-ray diffraction pattern comprises a peak at 6.93 degrees.

40. A pharmaceutical composition wherein the composition is a solvate form and is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said form is a modafinil methanol solvate and said X-ray diffraction pattern comprises peaks at 6.15, 9.89, and 20.07 degrees;

(b) said form is a modafinil methanol solvate and said X-ray diffraction pattern comprises peaks at 6.15 and 9.89 degrees;

(c) said form is a modafinil methanol solvate and said X-ray diffraction pattern comprises peaks at 12.25 and 17.97 degrees;

(d) said form is a modafinil methanol solvate and said X-ray diffraction pattern comprises peaks at 20.07 and 21.85 degrees; or

(e) said form is a modafinil methanol solvate and said X-ray diffraction pattern comprises a peak at 6.15 degrees.

41. A pharmaceutical composition wherein the composition is a solvate form and is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said form is a modafinil nitromethane solvate and said X-ray diffraction pattern comprises peaks at 6.17, 9.77, and 20.07 degrees;

(b) said form is a modafinil nitromethane solvate and said X-ray diffraction pattern comprises peaks at 12.29 and 15.89 degrees;

(c) said form is a modafinil nitromethane solvate and said X-ray diffraction pattern comprises peaks at 6.17 and 20.07 degrees;

(d) said form is a modafinil nitromethane solvate and said X-ray diffraction pattern comprises peaks at 9.77 and 22.17 degrees; or

(e) said form is a modafinil nitromethane solvate and said X-ray diffraction pattern comprises a peak at 6.17 degrees.

42. A pharmaceutical composition wherein the composition is a solvate form and is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said form is a modafinil acetone solvate and said X-ray diffraction pattern comprises peaks at 6.11, 9.53, and 15.81 degrees;

(b) said form is a modafinil acetone solvate and said X-ray diffraction pattern comprises peaks at 6.11 and 9.53 degrees;

(c) said form is a modafinil acetone solvate and said X-ray diffraction pattern comprises peaks at 15.81 and 20.03 degrees;

(d) said form is a modafinil acetone solvate and said X-ray diffraction pattern comprises peaks at 18.11 and 21.63 degrees; or

(e) said form is a modafinil acetone solvate and said X-ray diffraction pattern comprises a peak at 6.11 degrees.

43. A pharmaceutical composition wherein:

(a) the composition is a polymorph and is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(i) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises peaks at 8.97, 10.15, and 20.39 degrees;

(ii) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises peaks at 8.97 and 18.19 degrees;

(iii) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises peaks at 10.15 and 20.39 degrees;

(iv) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises peaks at 15.77 and 19.25 degrees; or

(v) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises a peak at 8.97 degrees; or

(b) the composition is characterized by a DSC thermogram, wherein said composition is a modafinil polymorph and said DSC thermogram comprises an endothermic transition at about 167 degrees C.

44. The pharmaceutical composition of claim 43, wherein the modafinil is R-(-)-modafinil.

45. The pharmaceutical composition of claim 44, wherein the composition is a mixture of R-(-)-modafinil Forms I and II.

46. A pharmaceutical composition wherein:

(a) the composition is a polymorph and is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(i) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises peaks at 7.21, 10.37, and 17.73 degrees;

(ii) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises peaks at 7.21 and 10.37 degrees;

(iii) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises peaks at 17.73 and 19.23 degrees;

(iv) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises peaks at 10.37 and 21.77 degrees; or

(v) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises a peak at 7.21 degrees; or

(b) the composition is characterized by a DSC thermogram, wherein said composition is a modafinil polymorph and said DSC thermogram comprises an endothermic transition at about 161 degrees C.

47. The pharmaceutical composition of claim 43, wherein the modafinil is R-(-)-modafinil.

48. The pharmaceutical composition of claim 44, wherein the composition is R-(-)-modafinil Form III.

49. A pharmaceutical composition wherein the composition is a polymorph and is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(a) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises peaks at 6.61, 10.39, and 16.49 degrees;

(b) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises peaks at 6.61 and 10.39 degrees;

(c) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises peaks at 13.99 and 17.73 degrees; or

(d) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises peaks at 20.87 and 22.31 degrees; or

(e) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises a peak at 6.61 degrees.

50. The pharmaceutical composition of claim 43, wherein the modafinil is R-(-)-modafinil.

51. The pharmaceutical composition of claim 44, wherein the composition is R-(-)-modafinil Form V.

52. A pharmaceutical composition wherein:

(a) the composition is a polymorph and is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(i) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises peaks at 7.79, 10.31, and 11.77 degrees;

(ii) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises peaks at 7.79 and 10.31 degrees;

(iii) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises peaks at 16.49 and 17.33 degrees;

(iv) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises peaks at 19.47 and 23.51 degrees; or

(v) said composition is a modafinil polymorph and said X-ray diffraction pattern comprises a peak at 7.79 degrees; or

(b) the composition is characterized by a DSC thermogram, wherein said composition is a modafinil polymorph and said DSC thermogram comprises an endothermic transition at about 147 degrees C.

53. The pharmaceutical composition of claim 43, wherein the modafinil is R-(-)-modafinil.

54. The pharmaceutical composition of claim 44, wherein the composition is R-(-)-modafinil Form IV.

55. The co-crystal of claim 1, wherein the co-crystal former is a carboxylic acid.

56. The co-crystal of claim 55, wherein a carboxylic acid functional group of the co-crystal former interacts with the primary amide or the S=O of modafinil by hydrogen bonding.

57. The co-crystal of claim 55, wherein a carboxylic acid functional group of the co-crystal former interacts with the periphery of the amide dimer of modafinil by hydrogen bonding.

58. The co-crystal of claim 55, wherein a carboxylic acid functional group of the co-crystal former interacts with the amide dimer and the S=O of modafinil by hydrogen bonding.

59. The co-crystal of claim 55, wherein a carboxylic acid functional group of the co-crystal former interacts with two amide dimers of modafinil by hydrogen bonding.

60. The co-crystal of claim 1, wherein the modafinil is R-(-)-modafinil.

61. The co-crystal of claim 1, wherein the modafinil is S-(+)-modafinil.

62. The co-crystal of claim 8, wherein the modafinil is R-(-)-modafinil.

63. The co-crystal of claim 8, wherein the modafinil is S-(+)-modafinil.

64. A process for preparing a pharmaceutical co-crystal composition comprising modafinil and a co-crystal former, comprising:

(a) providing modafinil and a co-crystal former, wherein the co-crystal former is a solid at room temperature;.

(b) grinding, heating, co-subliming, co-melting, or contacting in solution the modafinil with the co-crystal former under crystallization conditions, so as to form a solid phase, wherein the modafinil and co-crystal former are hydrogen bonded to each other;

(c) isolating co-crystals formed thereby; and

(d) incorporating the co-crystals into a pharmaceutical composition.

65. The process of claim 64, wherein:

(a) the co-crystal former is selected from a co-crystal former of Table I or Table II; or

(b) the co-crystal former has at least one functional group selected from the group consisting of ether, thioether, alcohol, thiol, aldehyde, ketone, thioketone, nitrate ester, phosphate ester, thiophosphate ester, ester, thioester, sulfate ester, carboxylic acid, phosphonic acid, phosphinic acid, sulfonic acid, amide, primary amine, secondary amine, ammonia, tertiary amine, sp2 amine, thiocyanate, cyanamide, oxime, nitrile diazo, organohalide, nitro, S-heterocyclic ring, thiophene, N-heterocyclic ring, pyrrole, O-heterocyclic ring, furan, epoxide, peroxide, hydroxamic acid, imidazole, and pyridine.

66. A process for preparing a pharmaceutical co-crystal composition comprising modafinil, a co-crystal former, and a third molecule, comprising:

(a) providing modafinil and a co-crystal former, wherein the co-crystal former is a solid at room temperature;

(b) grinding, heating, co-subliming, co-melting, or contacting in solution the modafinil with the co-crystal former under crystallization conditions, so as to form a solid phase, wherein the modafinil and the third molecule

are bonded to each other, and further wherein the co-crystal former and the third molecule are hydrogen bonded to each other;

(c) isolating co-crystals formed thereby; and

(d) incorporating the co-crystals into a pharmaceutical composition.

67. The process of claim 66, wherein:

(a) the co-crystal former is selected from a co-crystal former of Table I or Table II; or

(b) the co-crystal former has at least one functional group selected from the group consisting of ether, thioether, alcohol, thiol, aldehyde, ketone, thioketone, nitrate ester, phosphate ester, thiophosphate ester, ester, thioester, sulfate ester, carboxylic acid, phosphonic acid, phosphinic acid, sulfonic acid, amide, primary amine, secondary amine, ammonia, tertiary amine, sp2 amine, thiocyanate, cyanamide, oxime, nitrile diazo, organohalide, nitro, S-heterocyclic ring, thiophene, N-heterocyclic ring, pyrrole, O-heterocyclic ring, furan, epoxide, peroxide, hydroxamic acid, imidazole, and pyridine.

68. A process for preparing a pharmaceutical co-crystal composition comprising modafinil and a second API, comprising:

(a) providing modafinil and a second API, wherein the second API is either a liquid or a solid at room temperature;

(b) grinding, heating, co-subliming, co-melting, or contacting in solution the modafinil and the second API under crystallization conditions, so as to form a solid phase, wherein the modafinil and the second API are hydrogen bonded to a molecule;

(c) isolating co-crystals formed thereby; and

(d) incorporating the co-crystals into a pharmaceutical composition.

69. The process of claim 68, wherein:

(a) modafinil is hydrogen bonded to the second API;

(b) the second API is a liquid at room temperature;

(c) the second API is a solid at room temperature; or

(d) the second API has at least one functional group selected from the group consisting of ether, thioether, alcohol, thiol, aldehyde, ketone, thioketone, nitrate ester, phosphate ester, thiophosphate ester, ester, thioester, sulfate ester, carboxylic acid, phosphonic acid, phosphinic acid, sulfonic acid, amide, primary amine, secondary amine, ammonia, tertiary amine, sp2 amine, thiocyanate, cyanamide, oxime, nitrile, diazo, organohalide, nitro, S-heterocyclic ring, thiophene, N-heterocyclic ring, pyrrole, O-heterocyclic ring, furan, epoxide, peroxide, hydroxamic acid, imidazole, and pyridine.

70. The process of claim 64, further comprising: incorporating a pharmaceutically acceptable diluent, excipient, or carrier.

71. A process of preparing a co-crystal comprising modafinil and a co-crystal former, comprising:

(a) providing modafinil and a co-crystal former;

(b) grinding, heating, co-subliming, co-melting, or contacting in solution the modafinil with the co-crystal former under crystallization conditions, so as to form a solid phase; and

(c) isolating co-crystals formed thereby;

wherein the co-crystal former is selected from the group consisting of malonic acid, benzamide, mandelic acid, glycolic acid, fumaric acid, and maleic acid.

72. A process for modulating the solubility of modafinil for use in a pharmaceutical composition, which process comprises:

(a) grinding, heating, co-subliming, co-melting, or contacting in solution the modafinil with a co-crystal forming compound under crystallization conditions, so as to form a co-crystal of the modafinil and the co-crystal forming compound;

(b) isolating the co-crystal, wherein the co-crystal has a modulated solubility as compared to the modafinil; and

(c) incorporating the co-crystal having modulated solubility into a pharmaceutical composition.

73. The process of claim 72, wherein the solubility of the co-crystal is increased as compared to the modafinil.

74. A process for modulating the dose response of modafinil for use in a pharmaceutical composition, which process comprises:

(a) grinding, heating, co-subliming, co-melting, or contacting in solution the modafinil with a co-crystal forming compound under crystallization conditions, so as to form a co-crystal of the modafinil and the co-crystal forming compound;

(b) isolating the co-crystal, wherein the co-crystal has a modulated dose response as compared to the modafinil; and

(c) incorporating the co-crystal having modulated dose response into a pharmaceutical composition.

75. The process of claim 74, wherein the dose response of the co-crystal is increased as compared to the modafinil.

76. A process for modulating the dissolution of modafinil for use in a pharmaceutical composition, which process comprises:

(a) grinding, heating, co-subliming, co-melting, or contacting in solution the modafinil with a co-crystal forming compound under crystallization

conditions, so as to form a co-crystal of the modafinil and the co-crystal forming compound;

(b) isolating the co-crystal, wherein the co-crystal has a modulated dissolution as compared to the modafinil; and

(c) incorporating the co-crystal having modulated dissolution into a pharmaceutical composition.

77. The process of claim 76, wherein the dissolution of the co-crystal is increased as compared to the modafinil.

78. A process for modulating the bioavailability of modafinil for use in a pharmaceutical composition, which process comprises:

(a) grinding, heating, co-subliming, co-melting, or contacting in solution the modafinil with a co-crystal forming compound under crystallization conditions, so as to form a co-crystal of the modafinil and the co-crystal forming compound;

(b) isolating the co-crystal, wherein the co-crystal has a modulated bioavailability as compared to the modafinil; and

(c) incorporating the co-crystal having modulated bioavailability into a pharmaceutical composition.

79. The process of claim 78, wherein the bioavailability of the co-crystal is increased as compared to the modafinil.

80. A process for increasing the stability of modafinil for use in a pharmaceutical composition, which process comprises:

(a) grinding, heating, co-subliming, co-melting, or contacting in solution the modafinil with a co-crystal forming compound under crystallization conditions, so as to form a co-crystal of the modafinil and the co-crystal forming compound;

(b) isolating the co-crystal, wherein the co-crystal has increased stability as compared to the modafinil; and

(c) incorporating the co-crystal having increased stability into a pharmaceutical composition.

81. A process for modulating the morphology of modafinil for use in a pharmaceutical composition, which process comprises:

(a) grinding, heating, co-subliming, co-melting, or contacting in solution modafinil with a co-crystal forming compound under crystallization conditions, so as to form a co-crystal of the modafinil and the co-crystal forming compound;

(b) isolating the co-crystal, wherein the co-crystal has a different morphology as compared to the modafinil; and

(c) incorporating the co-crystal having modulated morphology into a pharmaceutical composition.

82. A method of making a polymorph of R-(-)-modafinil, comprising:

(a) providing R-(-)-modafinil; and

(b) crystallizing the polymorph of R-(-)-modafinil from an appropriate solvent.

83. A method of making R-(-)-modafinil form I and form II, comprising:

(a) providing R-(-)-modafinil; and

(b) crystallizing the R-(-)-modafinil form I and form II from ethanol.

84. A method of making R-(-)-modafinil form III, comprising:

(a) providing R-(-)-modafinil; and

(b) crystallizing the R-(-)-modafinil form III from ethanol and isopropyl alcohol.

85. A method of making R-(-)-modafinil form IV, comprising:

(a) providing R-(-)-modafinil; and

(b) crystallizing the R-(-)-modafinil form IV from ethyl acetate and ethanol.

86. A method of making R-(-)-modafinil form V, comprising:

(a) providing R-(-)-modafinil; and

(b) crystallizing the R-(-)-modafinil form V from ethyl acetate and ethanol.

87. A pharmaceutical composition comprising a co-crystal of modafinil.

88. The pharmaceutical composition according to claim 87, further comprising a pharmaceutically acceptable diluent, excipient, or carrier.

89. A method for treating a subject suffering from excessive daytime sleepiness associated with narcolepsy, multiple sclerosis related fatigue, infertility, eating disorders, attention deficit hyperactivity disorder (ADHD), Parkinson's disease, incontinence, sleep apnea, or myopathies, which comprises administering to a subject a therapeutically effective amount of a co-crystal comprising modafinil.

90. The method according to claim 89, wherein the subject is a human subject.

91. A pharmaceutical composition wherein:

(a) the composition is an R-(-)-modafinil polymorph and is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(i) said composition is an R-(-)-modafinil polymorph and said X-ray diffraction pattern comprises peaks at 8.97, 10.15, and 15.77 degrees;

(ii) said composition is an R-(-)-modafinil polymorph and said X-ray diffraction pattern comprises peaks at 8.97 and 19.25 degrees;

(iii) said composition is an R-(-)-modafinil polymorph and said X-ray diffraction pattern comprises peaks at 10.15 and 15.77 degrees;

(iv) said composition is an R-(-)-modafinil polymorph and said X-ray diffraction pattern comprises peaks at 18.19 and 19.25 degrees; or

(vi) said composition is an R-(-)-modafinil polymorph and said X-ray diffraction pattern comprises a peak at 8.97 degrees; or

(b) the composition is characterized by a DSC thermogram, wherein said composition is an R-(-)-modafinil polymorph and said DSC thermogram comprises an endothermic transition at about 167 degrees C.

92. A pharmaceutical composition wherein:

(a) the composition is an R-(-)-modafinil polymorph and is characterized by a powder X-ray diffraction pattern comprising peaks expressed in terms of 2-theta angles, wherein:

(i) said composition is an R-(-)-modafinil polymorph and said X-ray diffraction pattern comprises peaks at 14.15, 17.41, and 18.19 degrees;

(ii) said composition is an R-(-)-modafinil polymorph and said X-ray diffraction pattern comprises peaks at 8.97 and 14.15 degrees;

(iii) said composition is an R-(-)-modafinil polymorph and said X-ray diffraction pattern comprises peaks at 10.15 and 17.41 degrees;

(iv) said composition is an R-(-)-modafinil polymorph and said X-ray diffraction pattern comprises peaks at 14.15 and 17.41 degrees; or

(vii) said composition is an R-(-)-modafinil polymorph and said X-ray diffraction pattern comprises a peak at 14.15 degrees; or

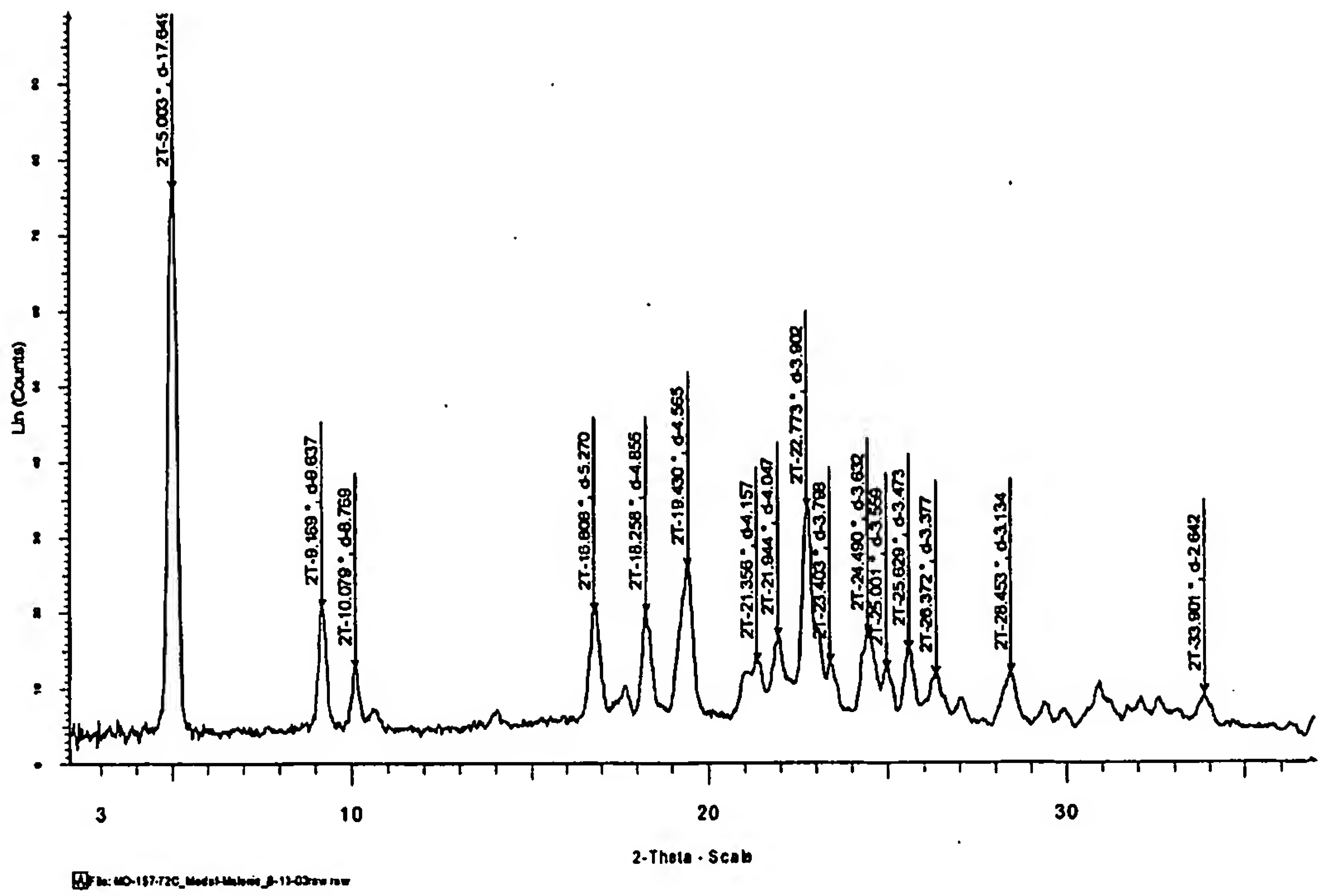
(b) the composition is characterized by a DSC thermogram, wherein said composition is an R-(-)-modafinil polymorph and said DSC thermogram comprises an endothermic transition at about 167 degrees C.

93. The pharmaceutical composition of claim 44, wherein the composition is R-(-)-modafinil Form I.

94. The pharmaceutical composition of claim 44, wherein the composition is R-(-)-modafinil Form II.

Abstract

Co-crystals and solvates of modafinil are formed and several important physical properties are modulated. The solubility, dissolution, bioavailability, dose response, and stability of modafinil can be modulated to improve efficacy in pharmaceutical compositions.



Angle 2-Theta Degrees
5.003
9.169
10.079
16.808
18.258
19.43
21.356
21.944
22.773
23.403
24.49
25.001
25.629
26.372
28.453
33.901

Figure 1

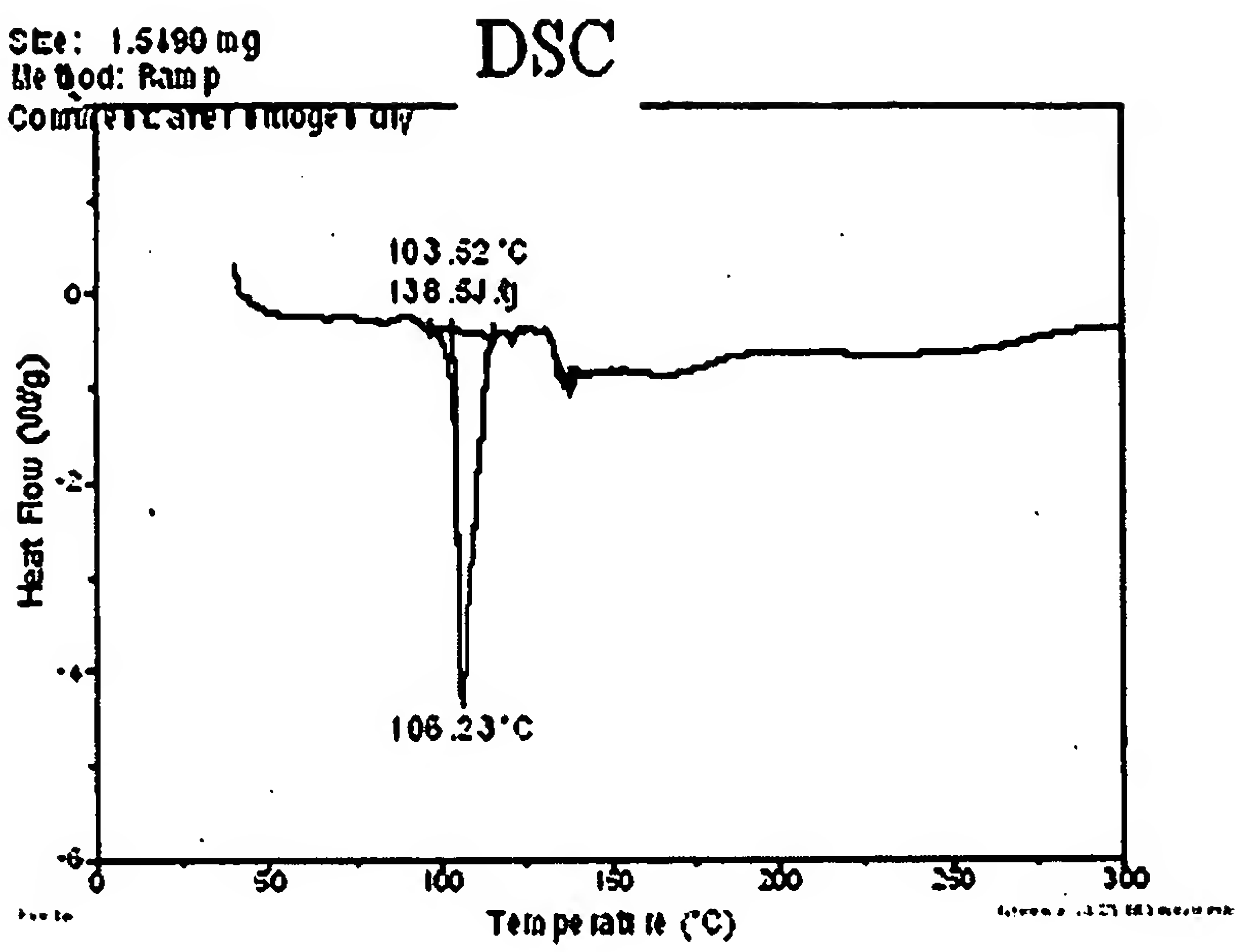


Figure 2

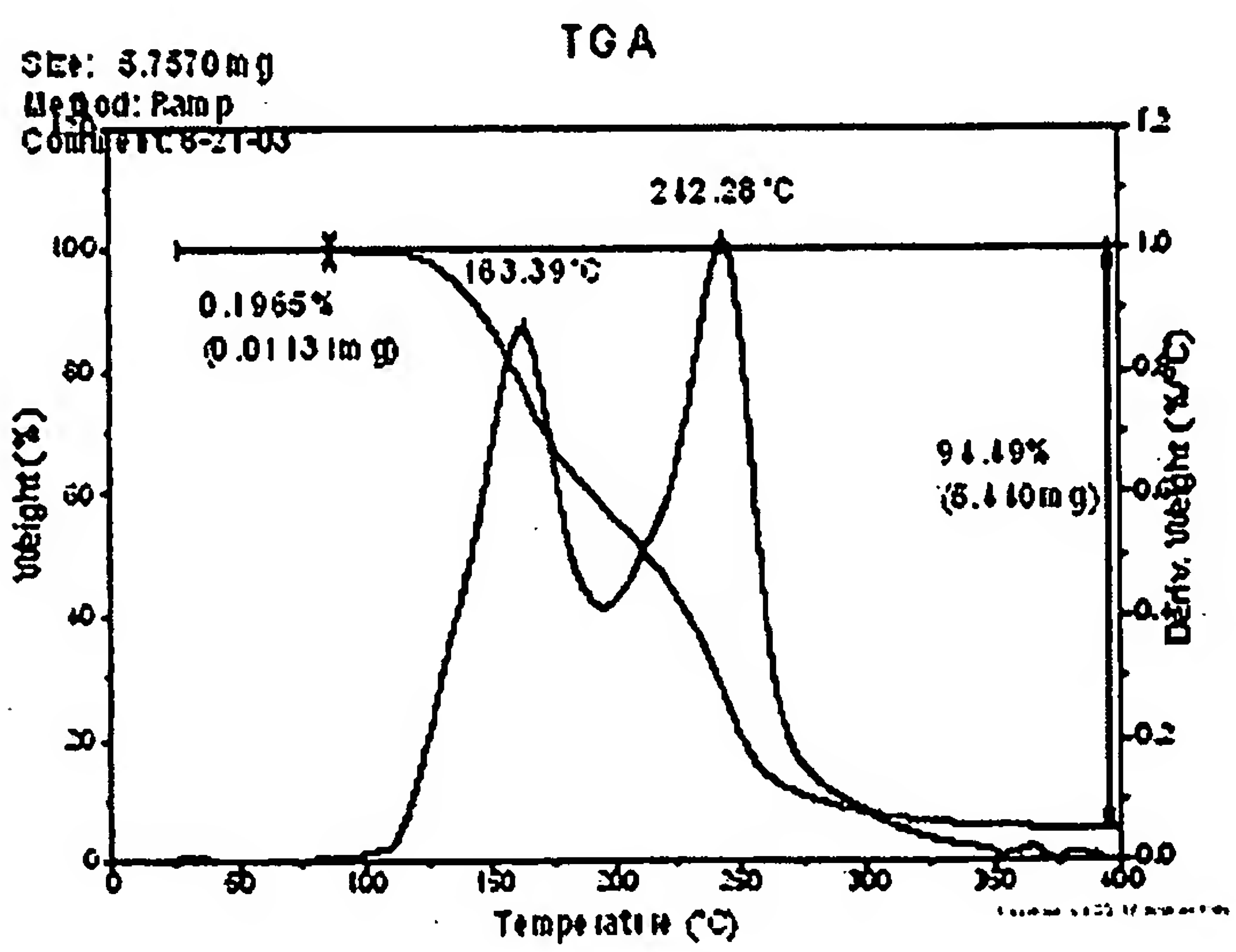
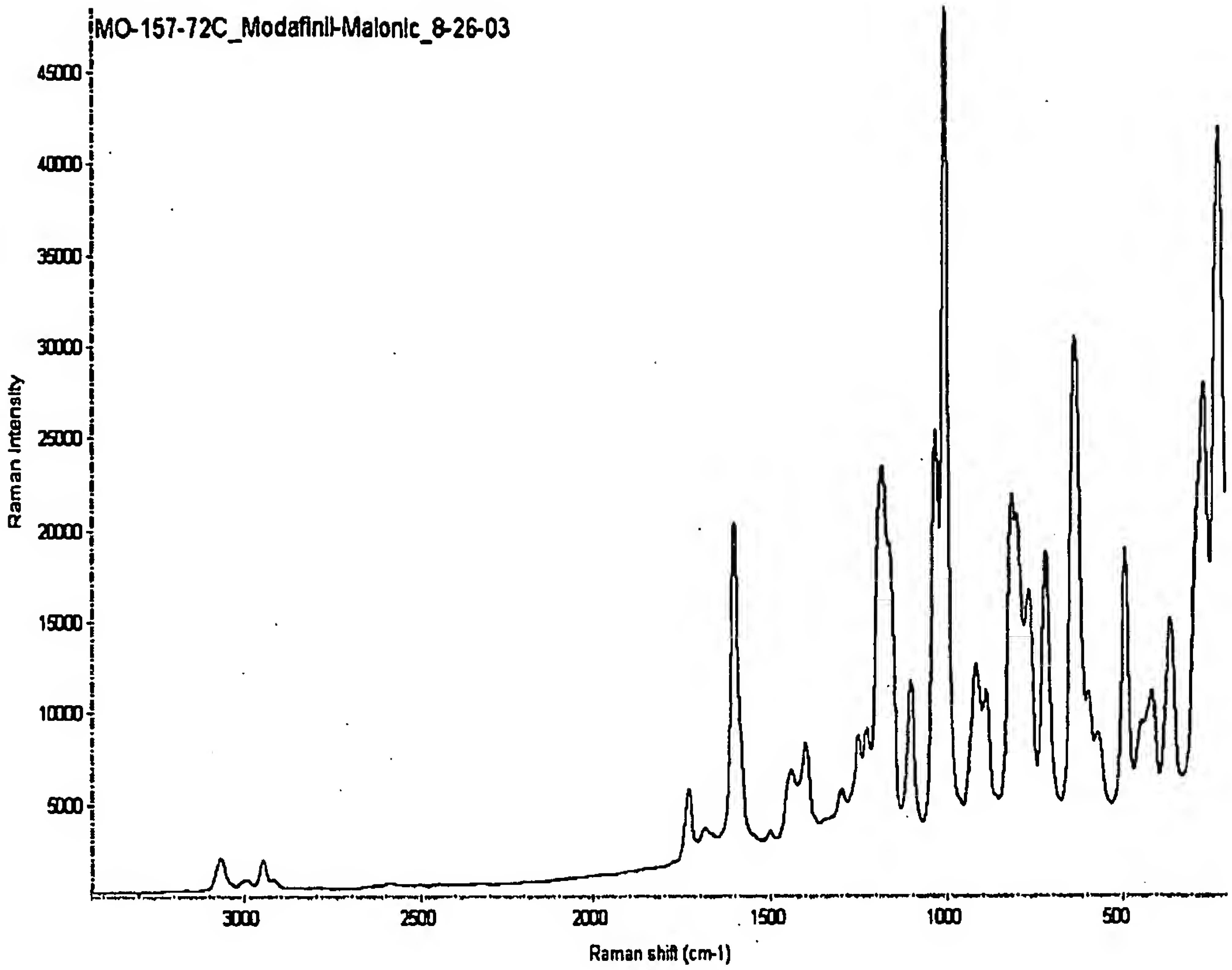


Figure 3



Position:	1004	Intensity:	48530.113
Position:	222	Intensity:	41631.178
Position:	633	Intensity:	30431.465
Position:	265	Intensity:	27632.348
Position:	1032	Intensity:	25424.109
Position:	1183	Intensity:	23465.441
Position:	814	Intensity:	21888.129
Position:	1601	Intensity:	20374.211
Position:	480	Intensity:	18917.469
Position:	718	Intensity:	18779.322
Position:	767	Intensity:	16891.541
Position:	381	Intensity:	15080.872
Position:	917	Intensity:	12651.283
Position:	1104	Intensity:	11708.740
Position:	889	Intensity:	11172.833
Position:	412	Intensity:	11137.415
Position:	1225	Intensity:	9027.109
Position:	1251	Intensity:	8844.833
Position:	1398	Intensity:	8252.702
Position:	1442	Intensity:	6738.694
Position:	1731	Intensity:	5730.559
Position:	1288	Intensity:	5700.058
Position:	3066	Intensity:	1936.514
Position:	2949	Intensity:	1912.835

Figure 4A

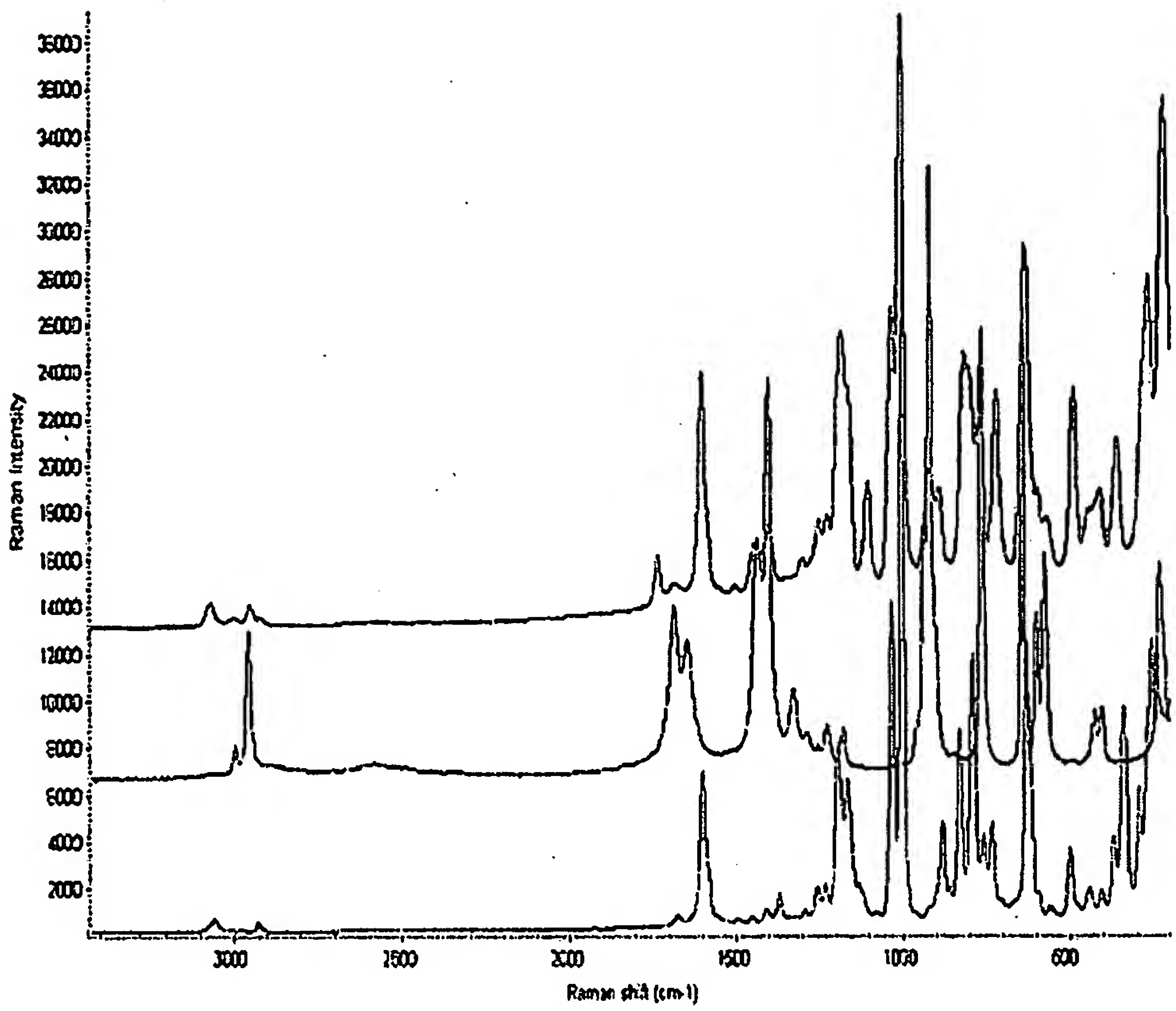
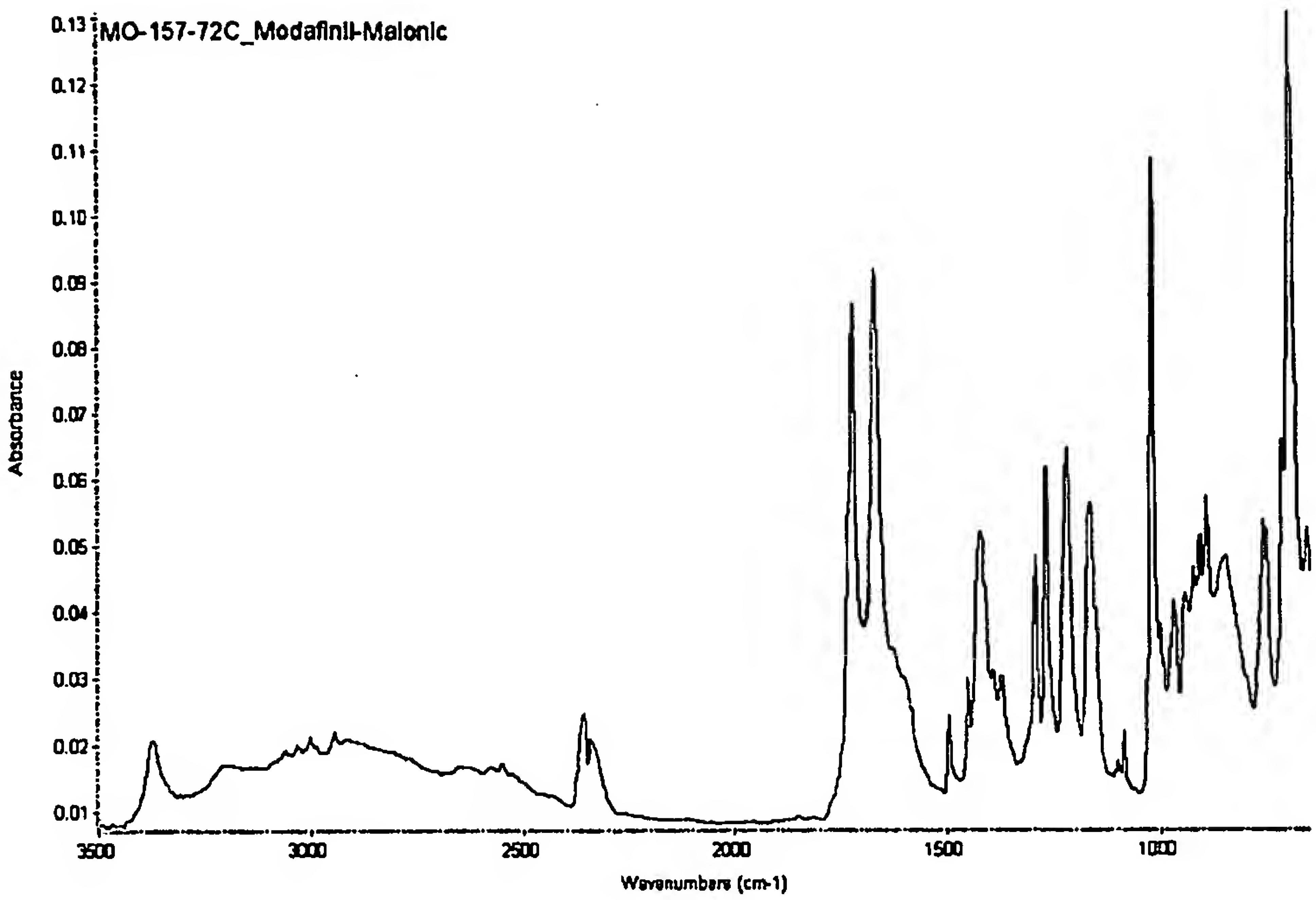


Figure 4B



Position:	700	Intensity:	0.131
Position:	1020	Intensity:	0.109
Position:	1668	Intensity:	0.0916
Position:	1718	Intensity:	0.0865
Position:	715	Intensity:	0.0664
Position:	1220	Intensity:	0.0647
Position:	1270	Intensity:	0.0624
Position:	892	Intensity:	0.0576
Position:	1164	Intensity:	0.0563
Position:	760	Intensity:	0.0538
Position:	655	Intensity:	0.0528
Position:	751	Intensity:	0.0527
Position:	1422	Intensity:	0.0518
Position:	907	Intensity:	0.0517
Position:	847	Intensity:	0.0485
Position:	1296	Intensity:	0.0482
Position:	921	Intensity:	0.0468
Position:	943	Intensity:	0.0428
Position:	969	Intensity:	0.0417
Position:	1004	Intensity:	0.0382
Position:	1372	Intensity:	0.0301
Position:	1451	Intensity:	0.0303
Position:	2360	Intensity:	0.0245
Position:	1496	Intensity:	0.0242
Position:	1086	Intensity:	0.0218
Position:	2942	Intensity:	0.0216
Position:	3001	Intensity:	0.0210
Position:	2342	Intensity:	0.0205
Position:	3372	Intensity:	0.0203

Figure 5A

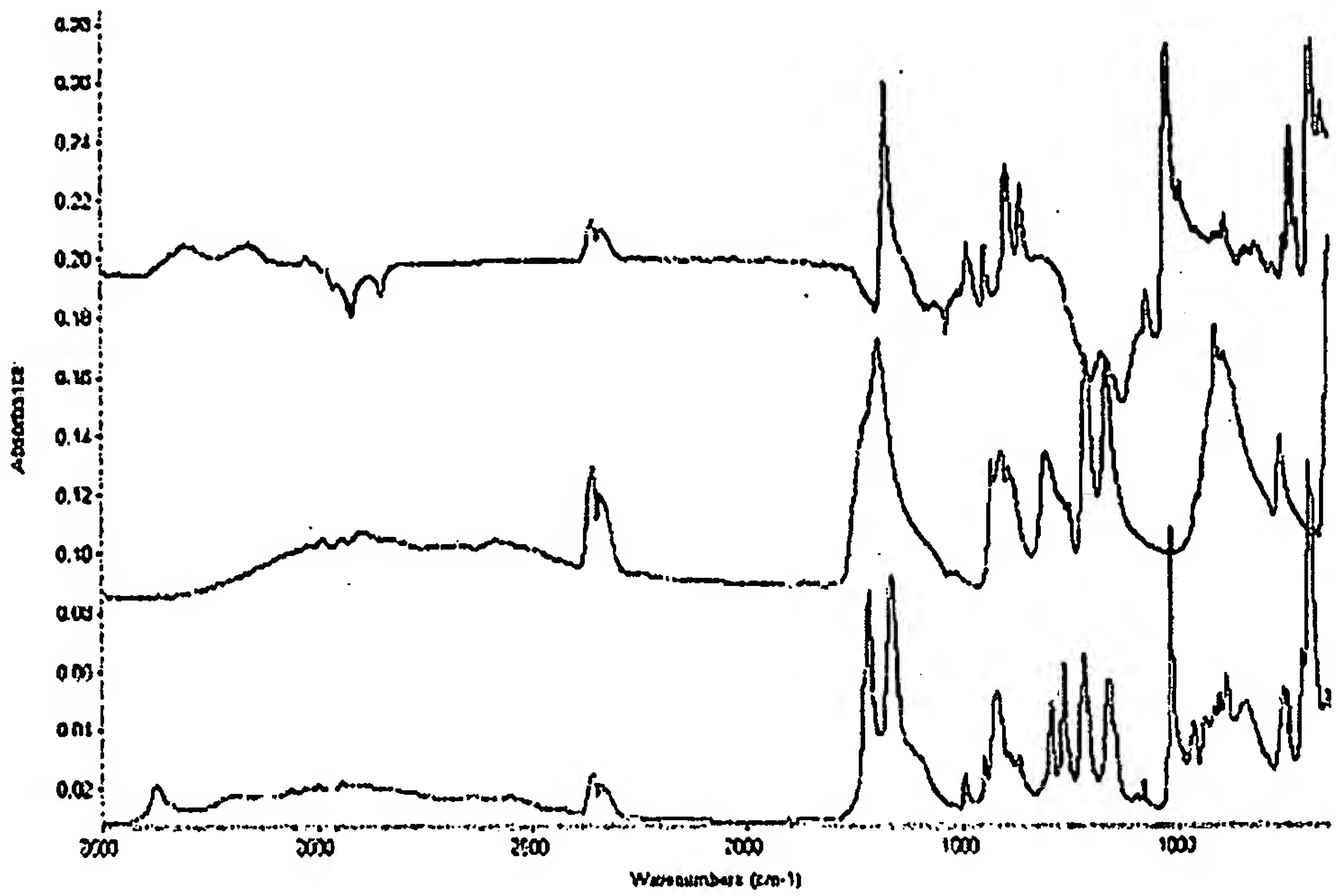


Figure 5B

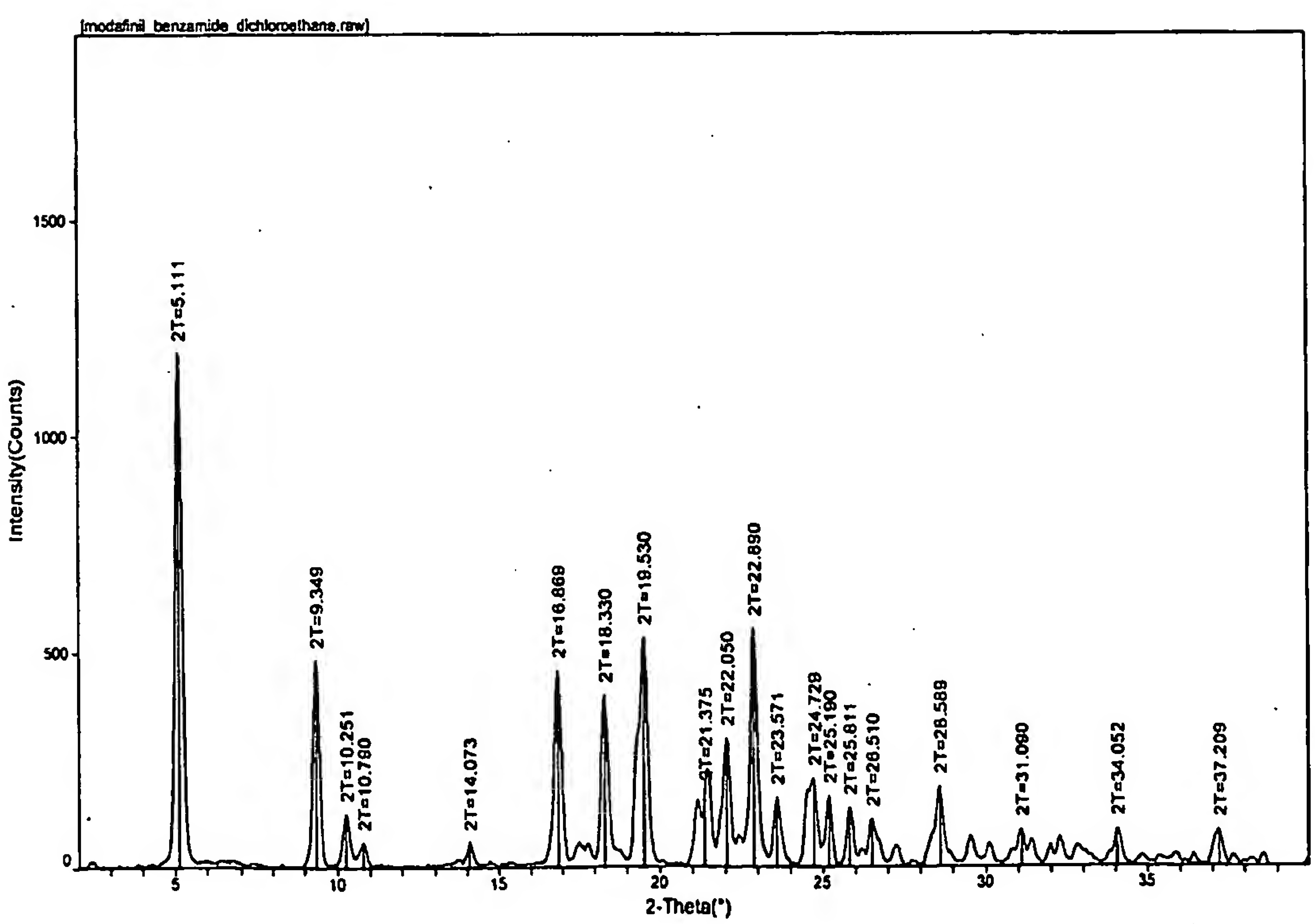


Figure 6

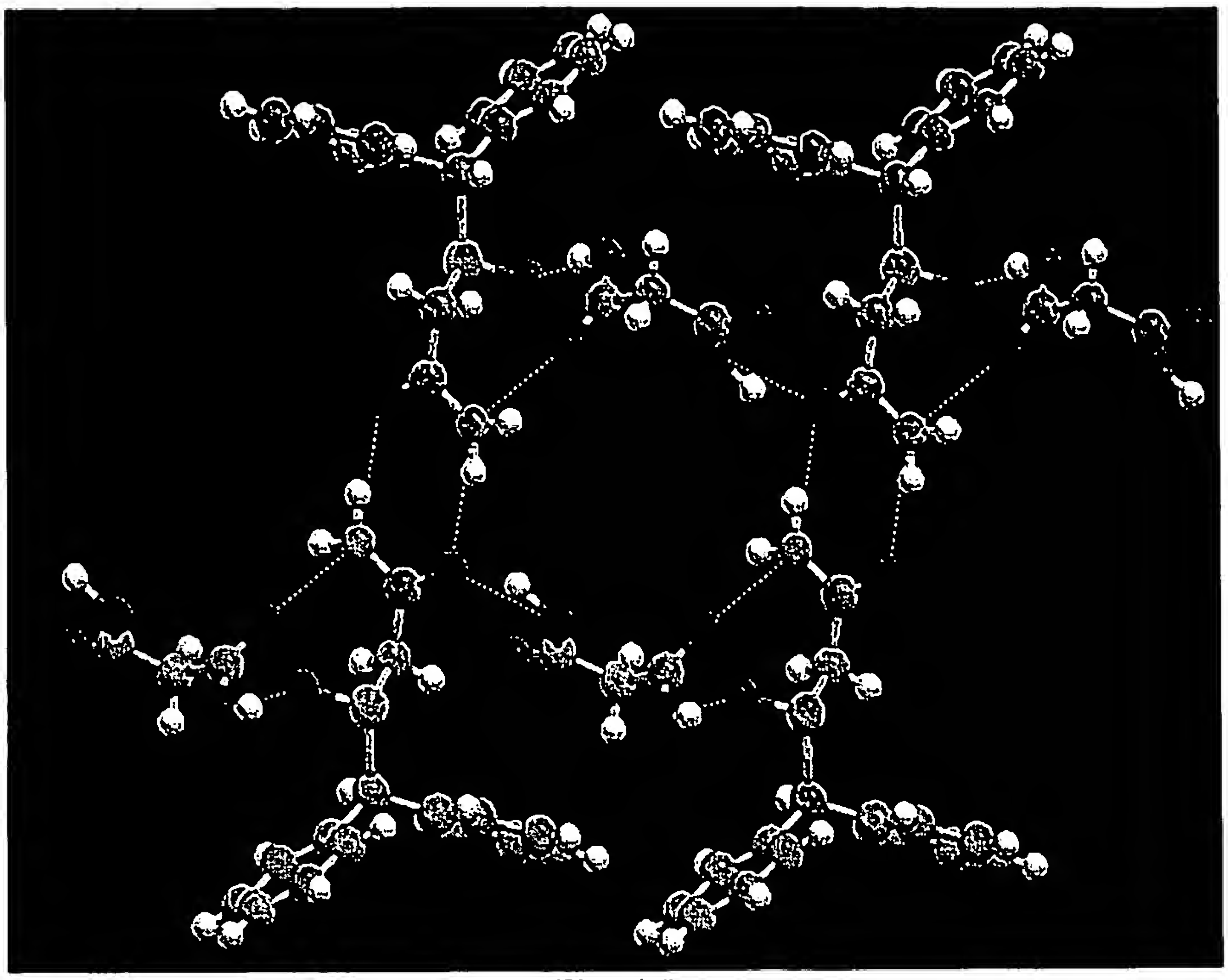


Figure 7

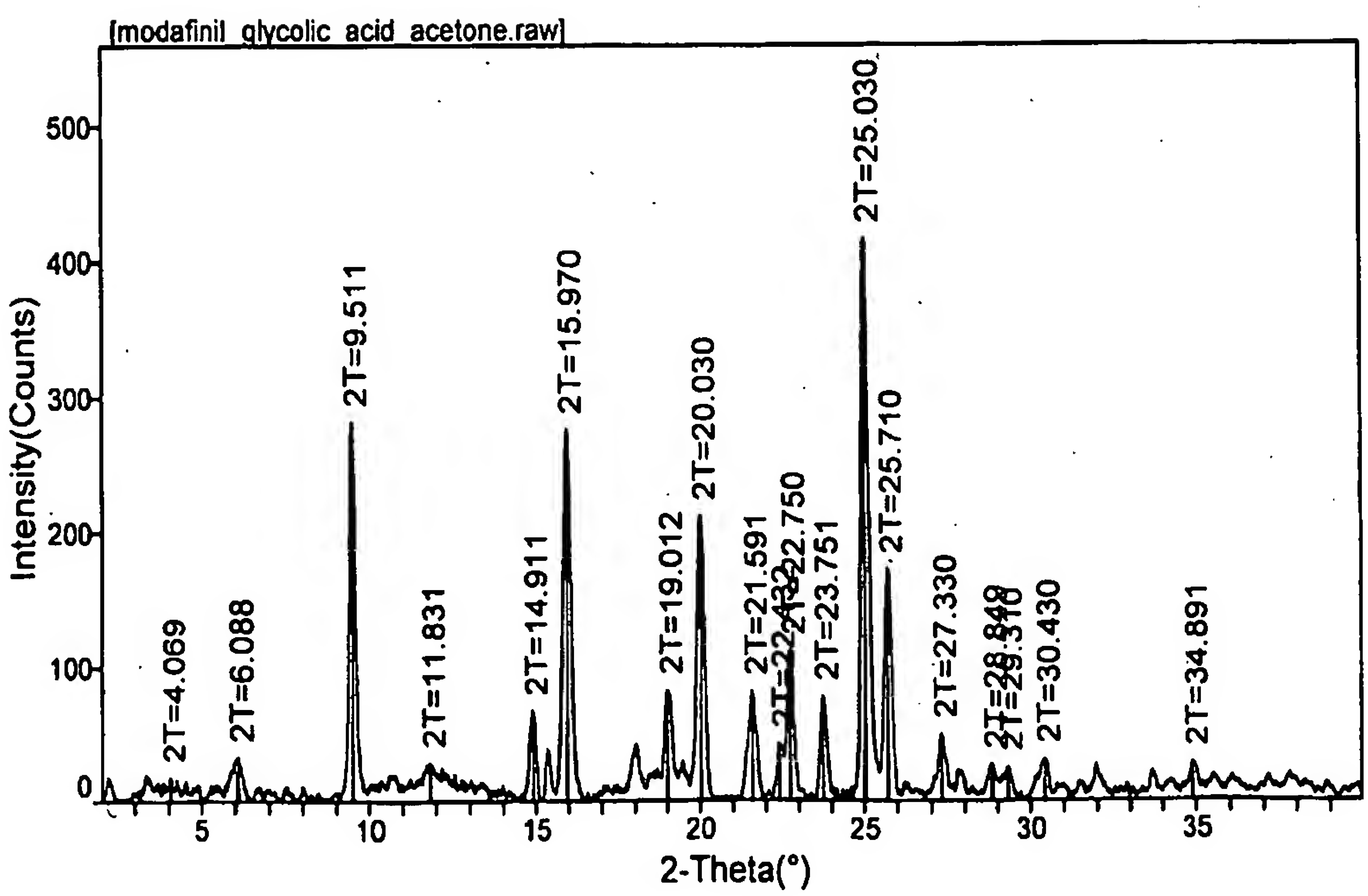
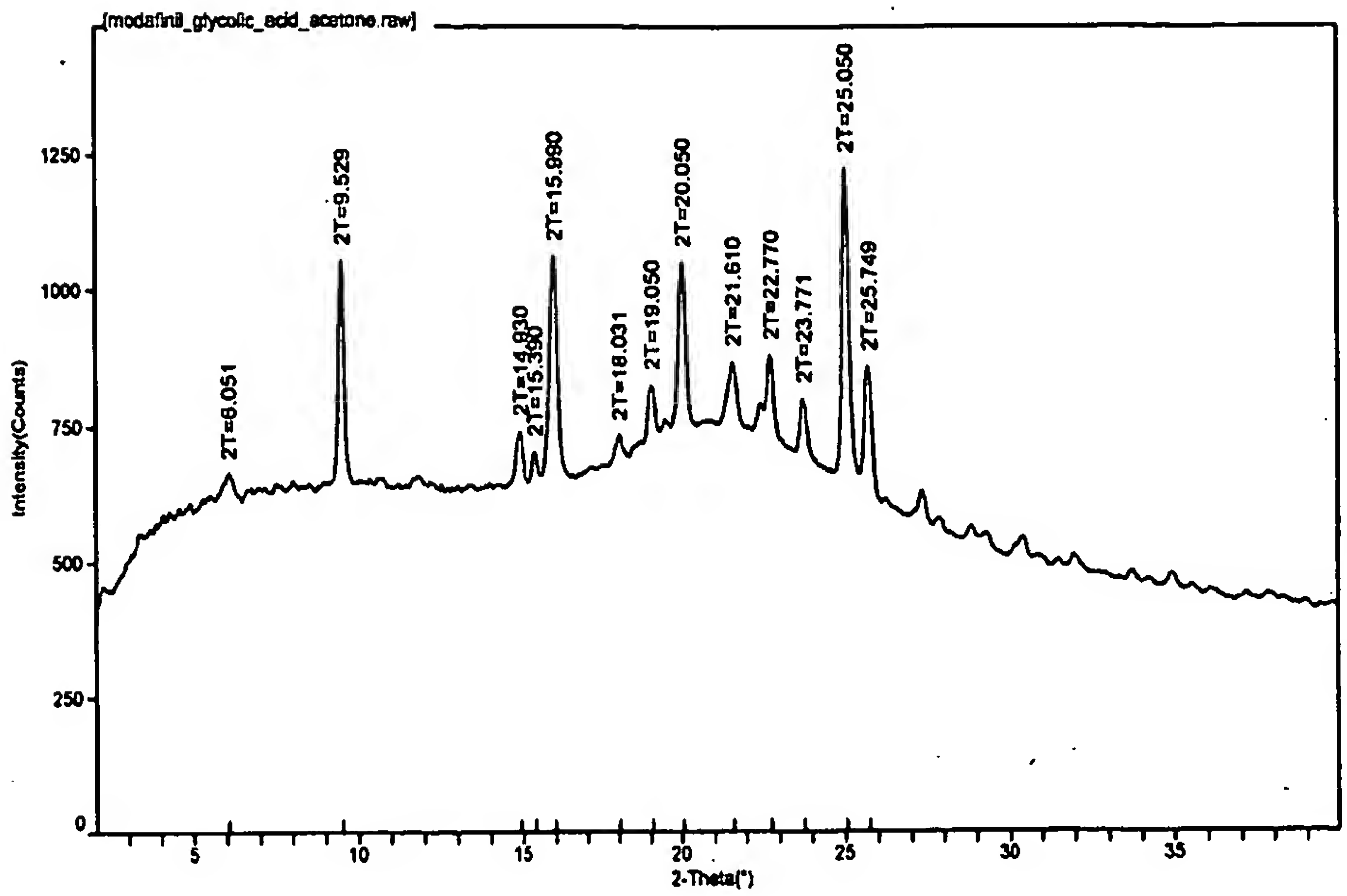


Figure 8A



[modafinil_glycolic_acid_acetone.raw]
2T=6.051
2T=9.529
2T=14.930
2T=15.390
2T=15.980
2T=18.031
2T=19.050
2T=20.050
2T=21.610
2T=22.770
2T=23.771
2T=25.050
2T=25.749
Intensity(Counts)
2-Theta(°)

Figure 8B

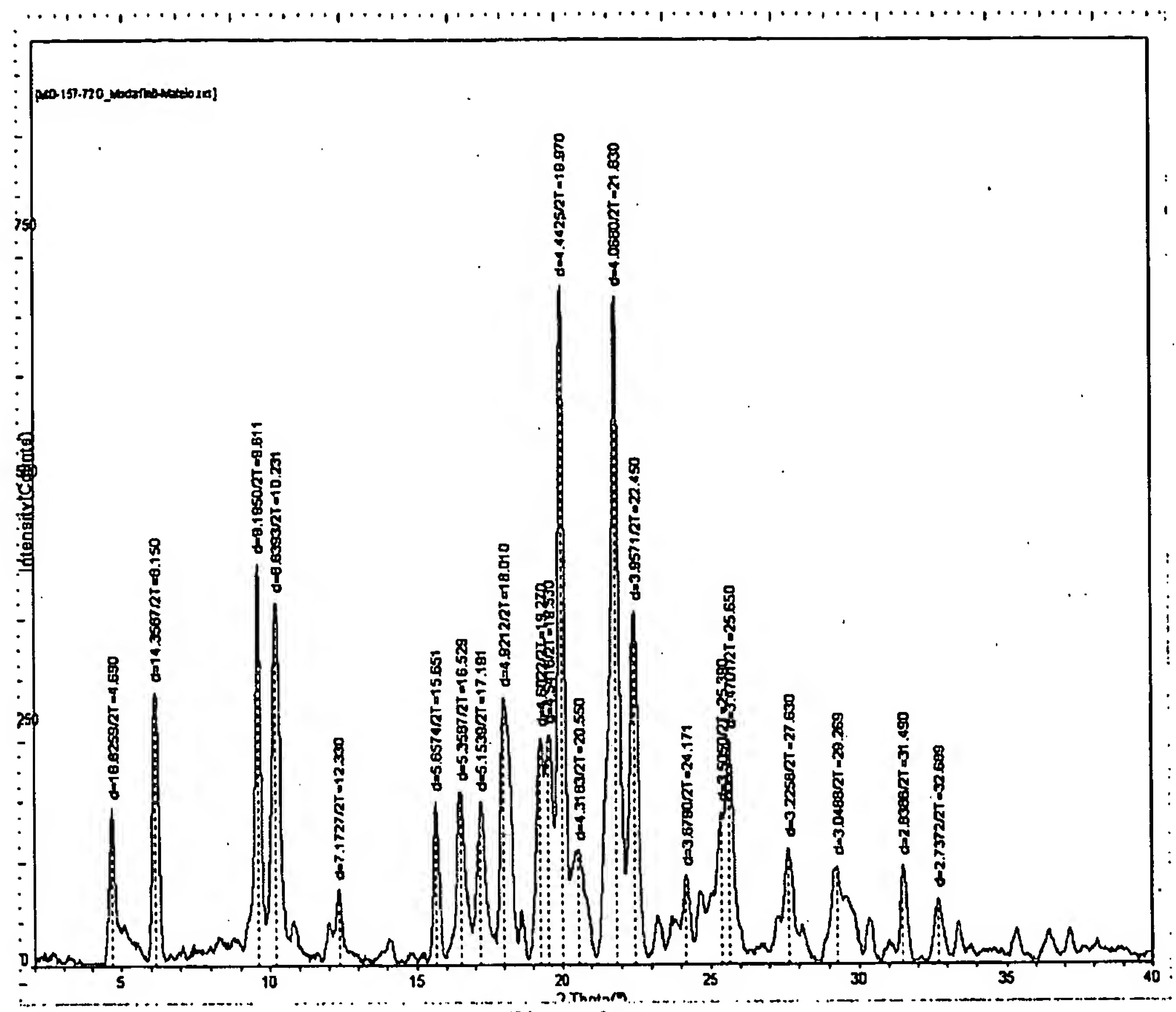


Figure 9A

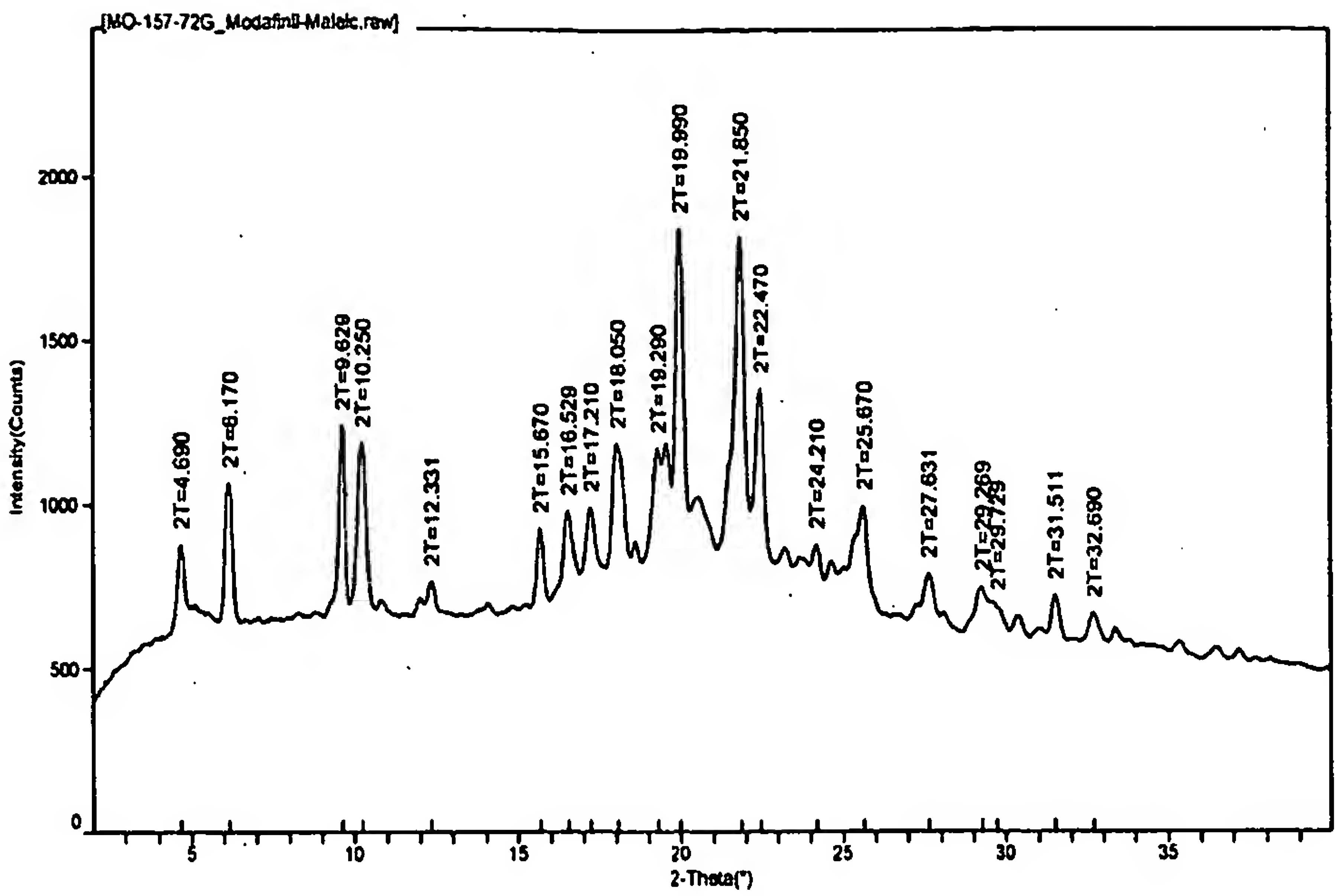


Figure 9B

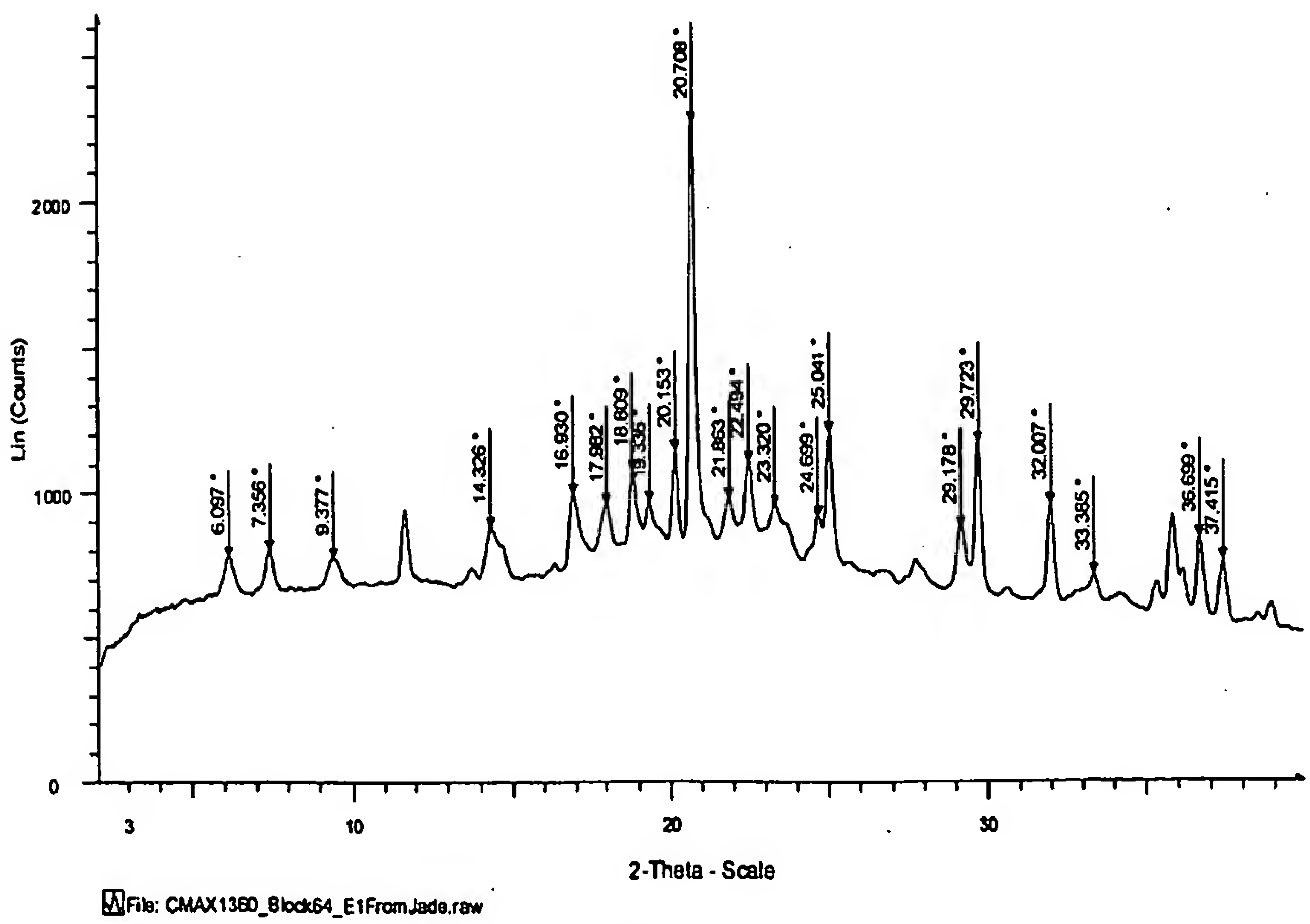


Figure 10

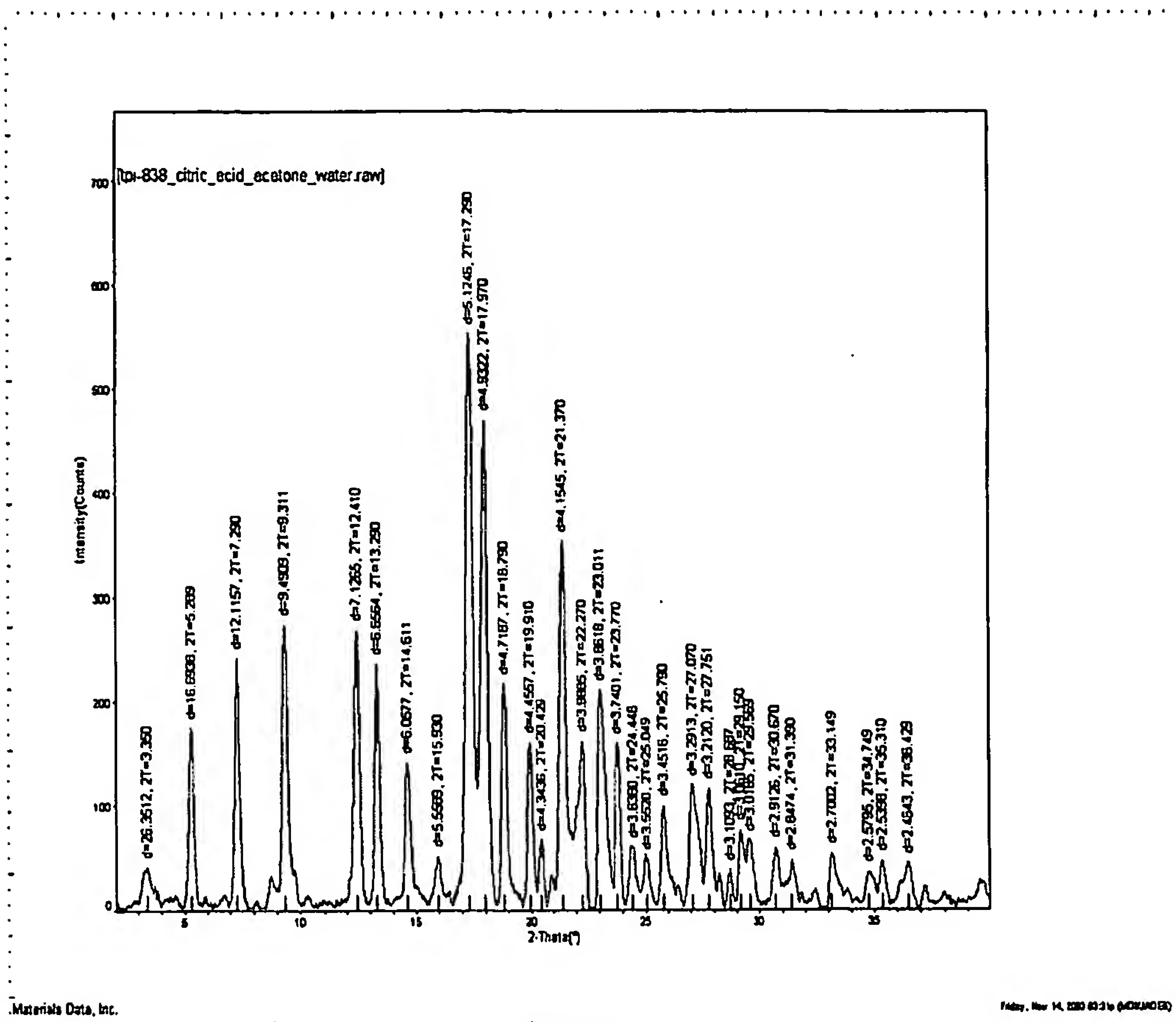

[tpi-838_citric_acid_acetone_water.raw]
Intensity(Counts)
2-Theta(°)
d=26.3512, 2T=3.350
d=16.6938, 2T=5.289
d=12.1157, 2T=7.290
d=9.4909, 2T=9.311
d=7.1265, 2T=12.410
d=6.6564, 2T=13.290
d=6.0577, 2T=14.611
d=5.5589, 2T=15.930
d=5.1245, 2T=17.290
d=4.9322, 2T=17.970
d=4.7187, 2T=18.790
d=4.4557, 2T=19.910
d=4.3436, 2T=20.429
d=4.1545, 2T=21.370
d=3.9885, 2T=22.270
d=3.8618, 2T=23.011
d=3.7401, 2T=23.770
d=3.6380, 2T=24.448
d=3.5520, 2T=25.049
d=3.4516, 2T=25.790
d=3.2913, 2T=27.070
d=3.2120, 2T=27.751
d=2.9126, 2T=30.670
d=2.8474, 2T=31.390
d=2.7002, 2T=33.149
d=2.5795, 2T=34.749
d=2.5398, 2T=35.310
d=2.4643, 2T=36.429
Materials Data, Inc.

Figure 11

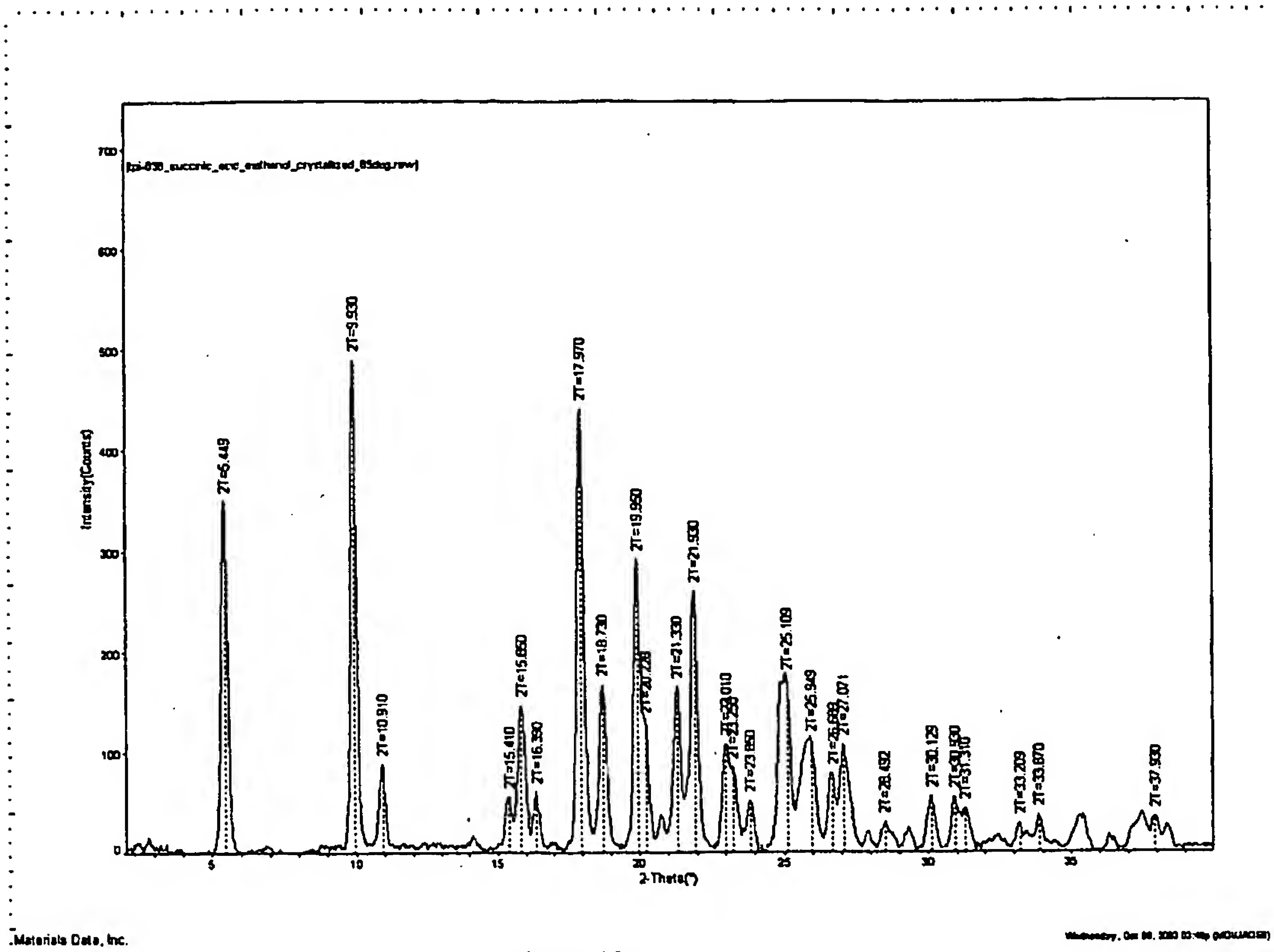


Figure 12A

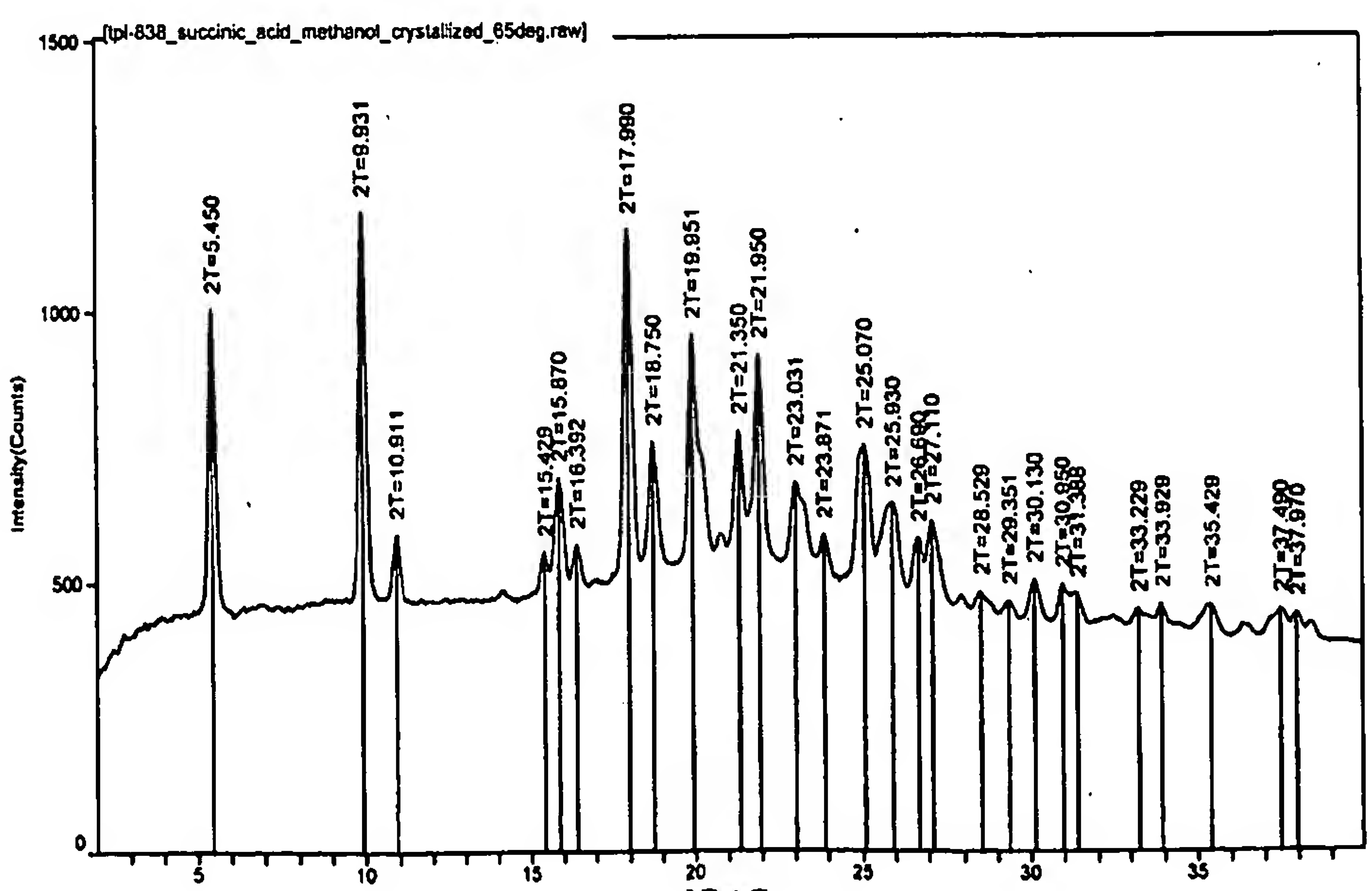


Figure 12B

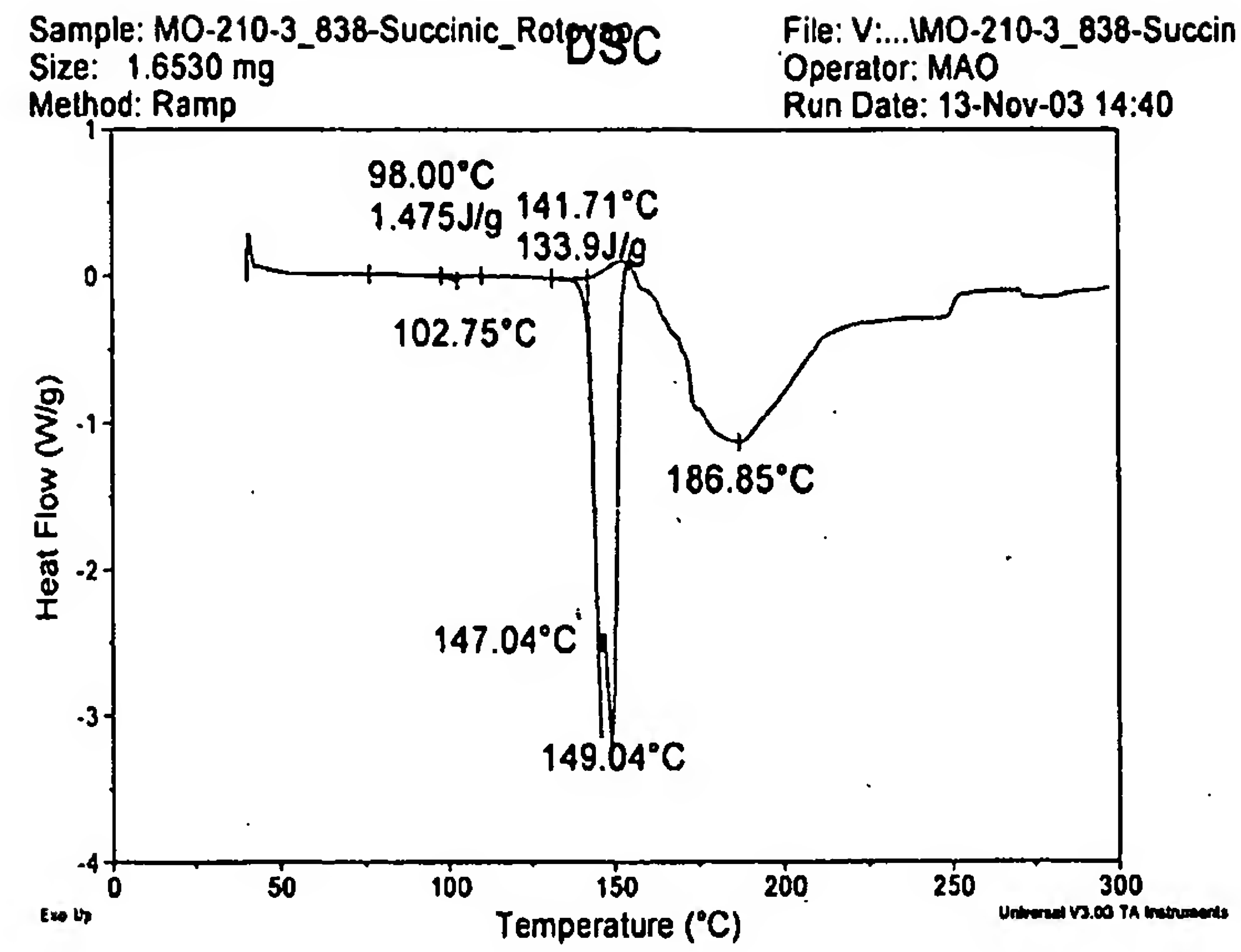


Figure 13

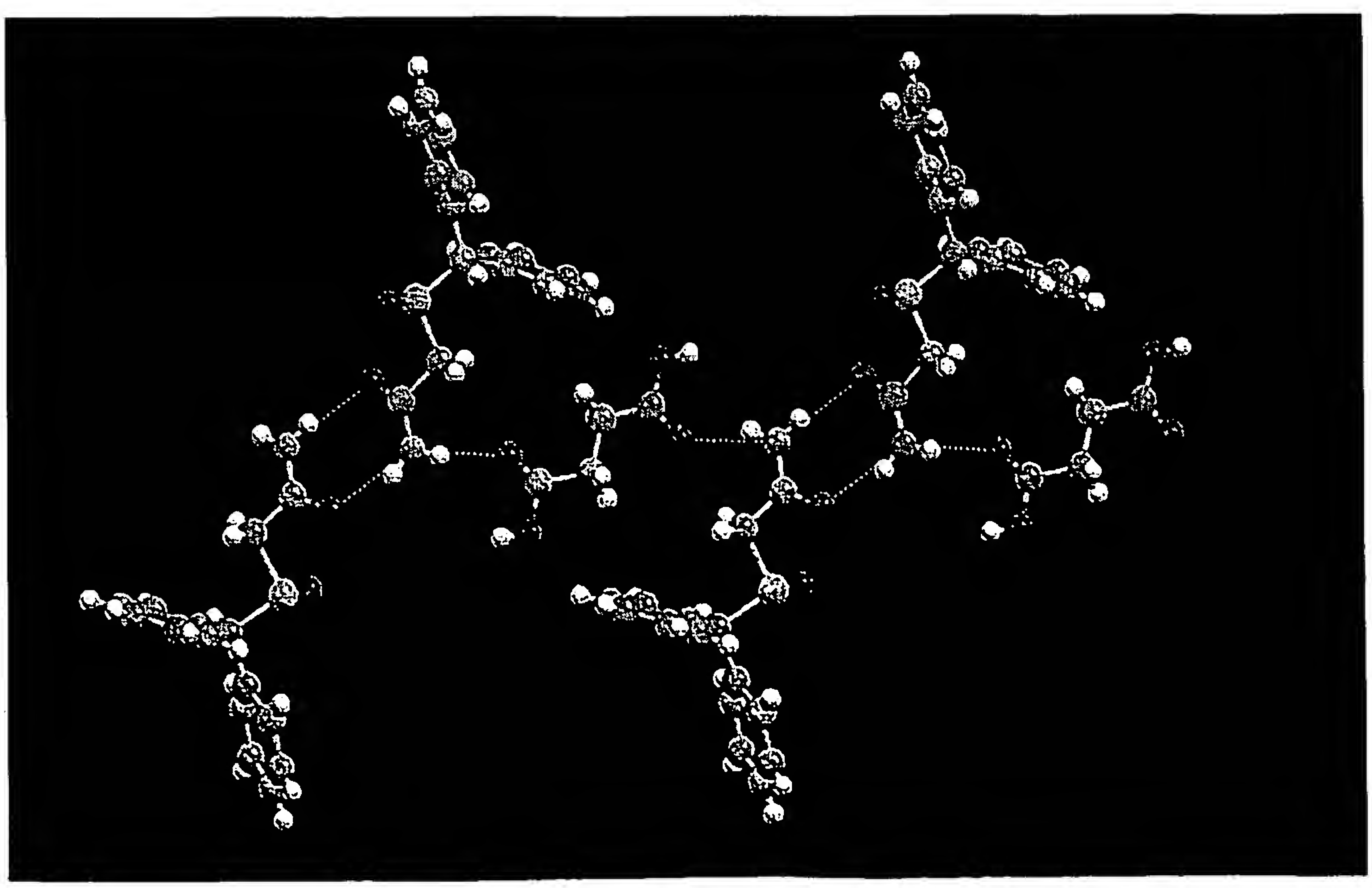


Figure 14

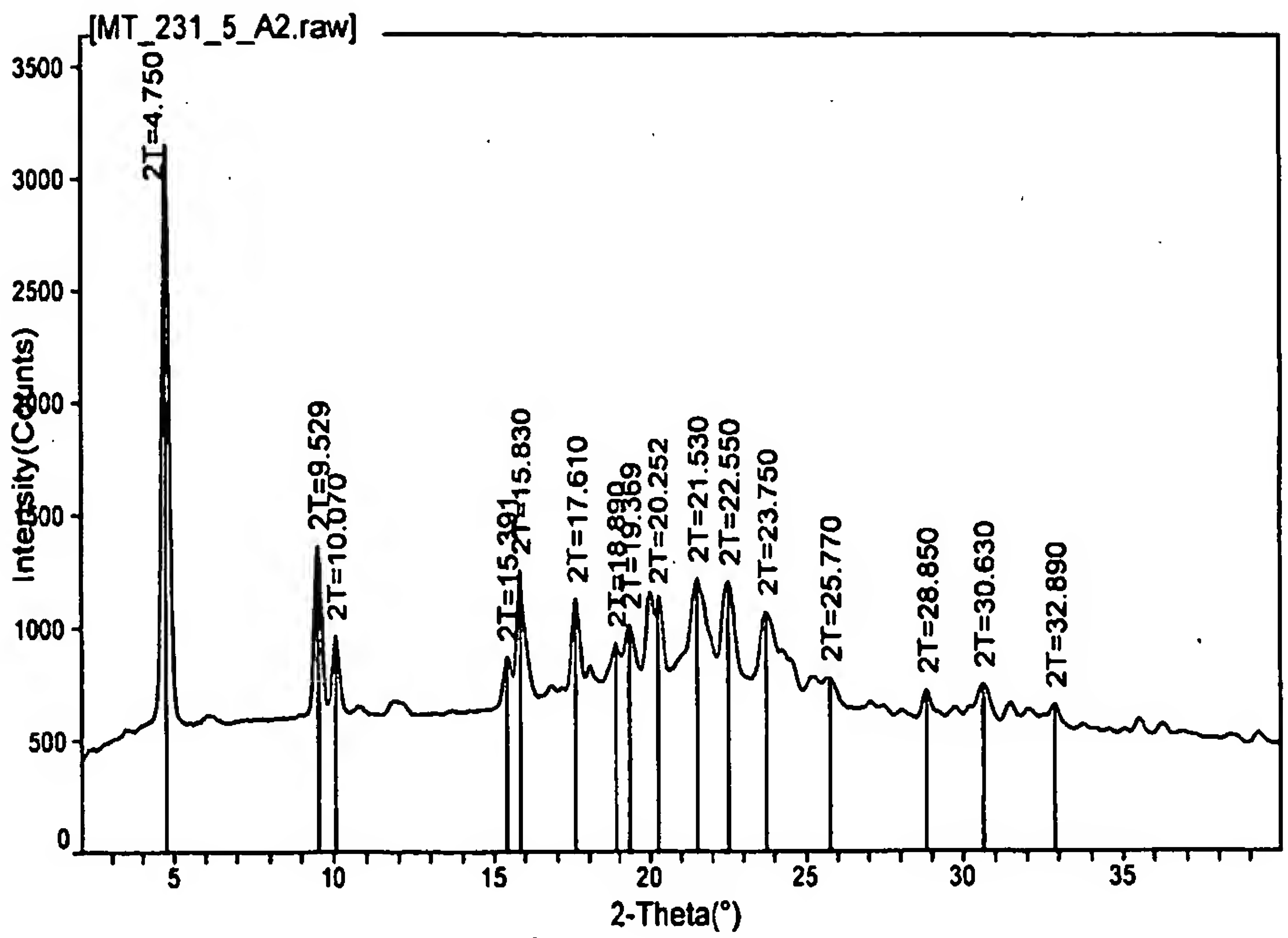


Figure 15

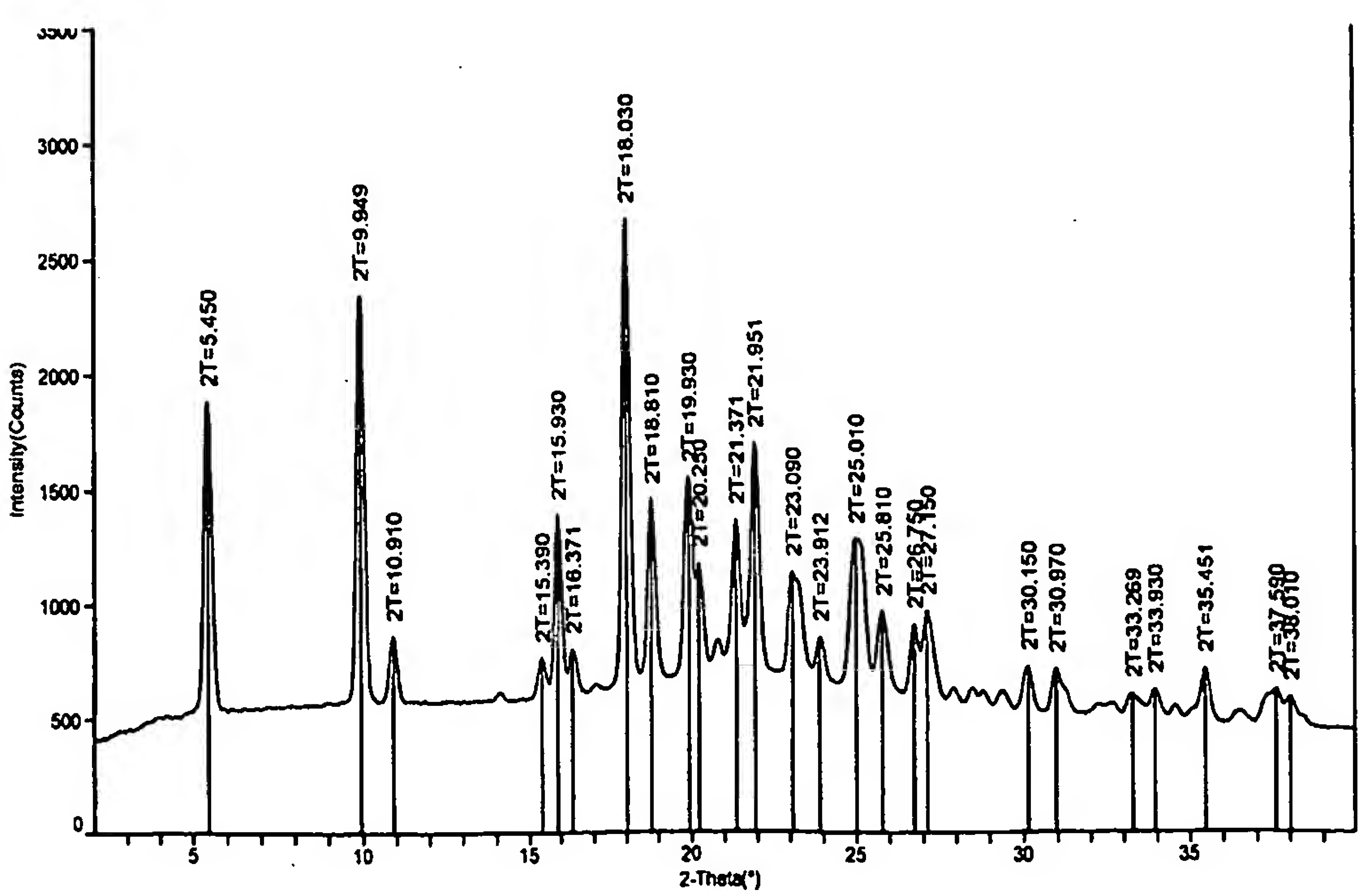


Figure 16

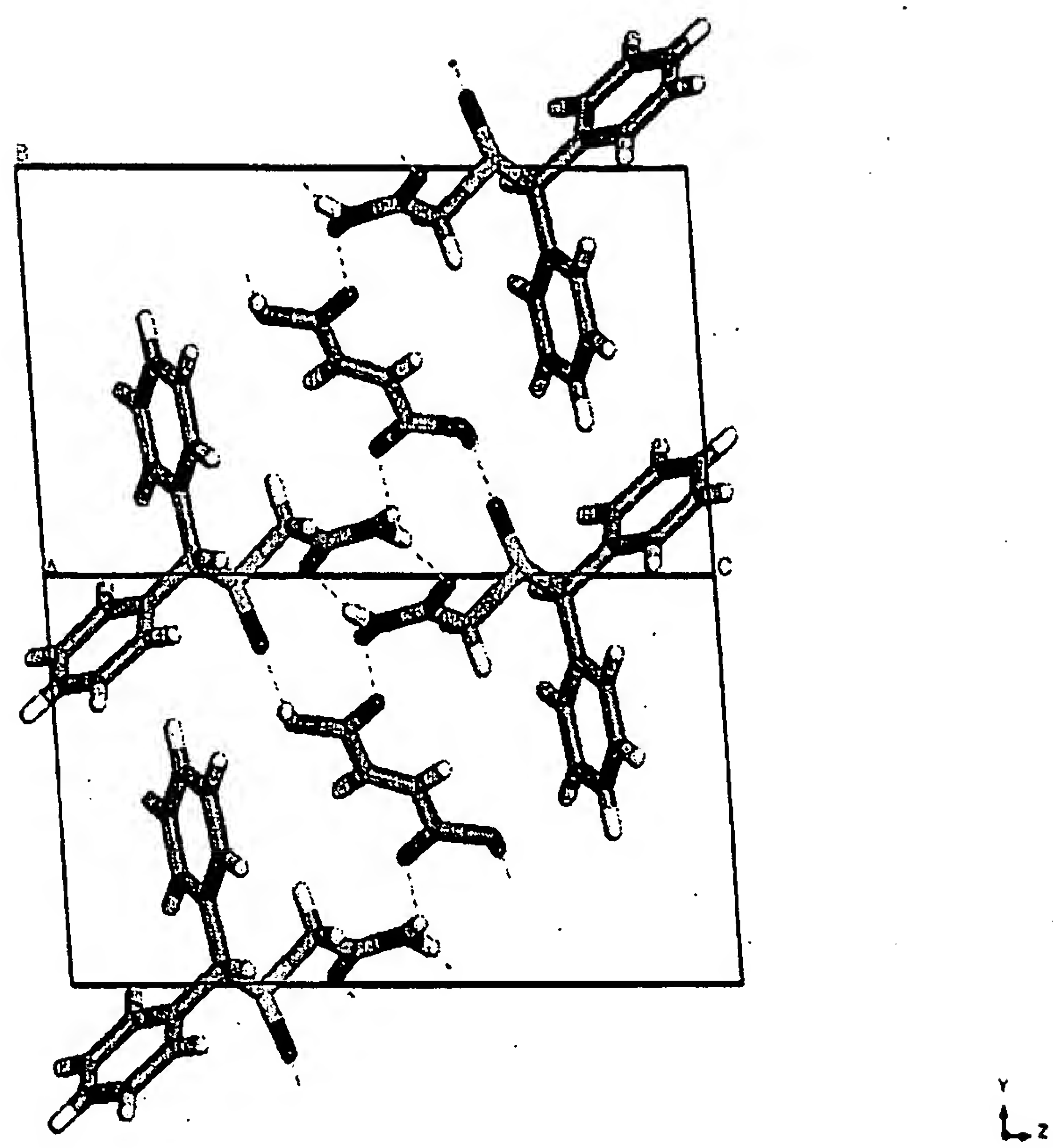


Figure 17

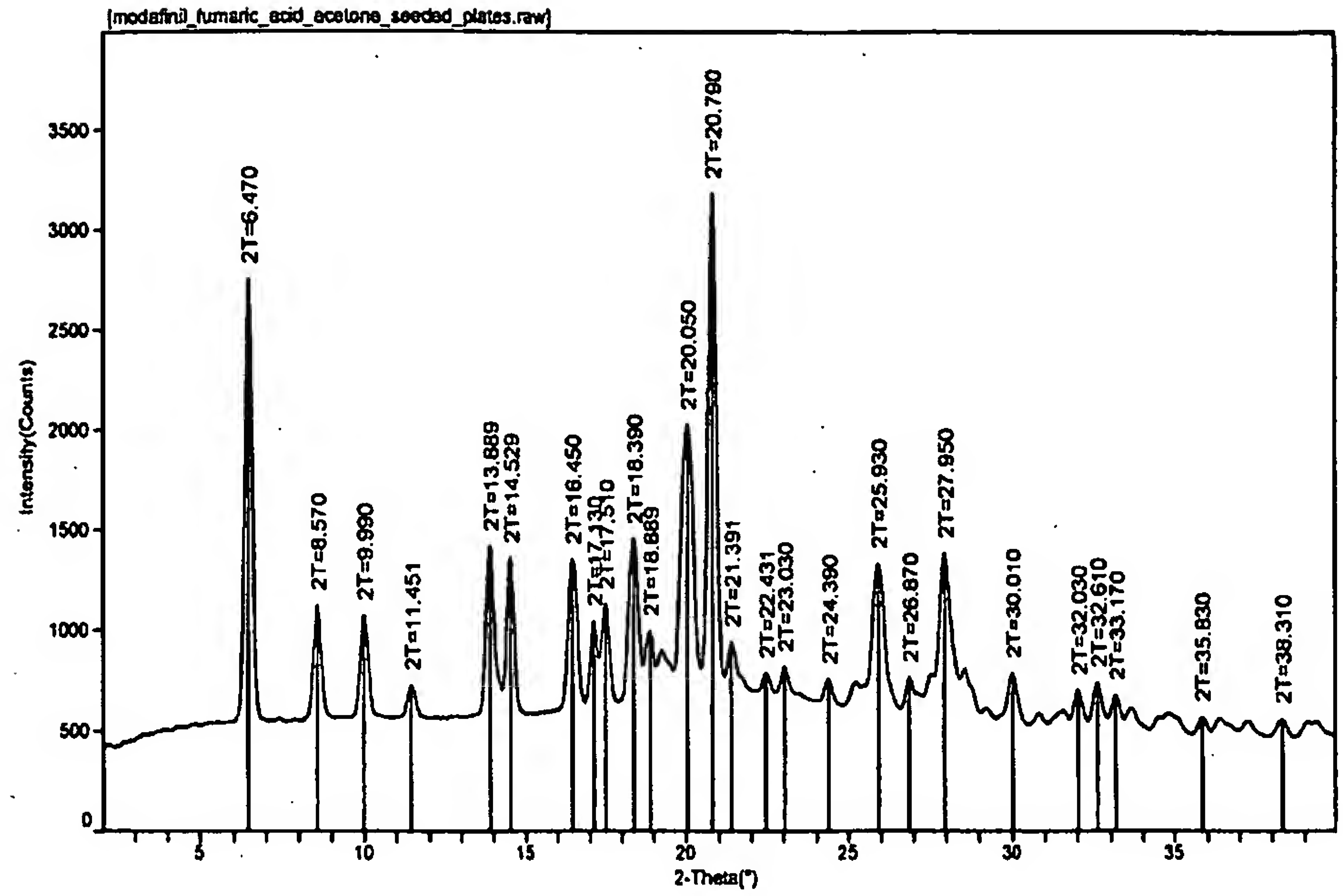


Figure 18

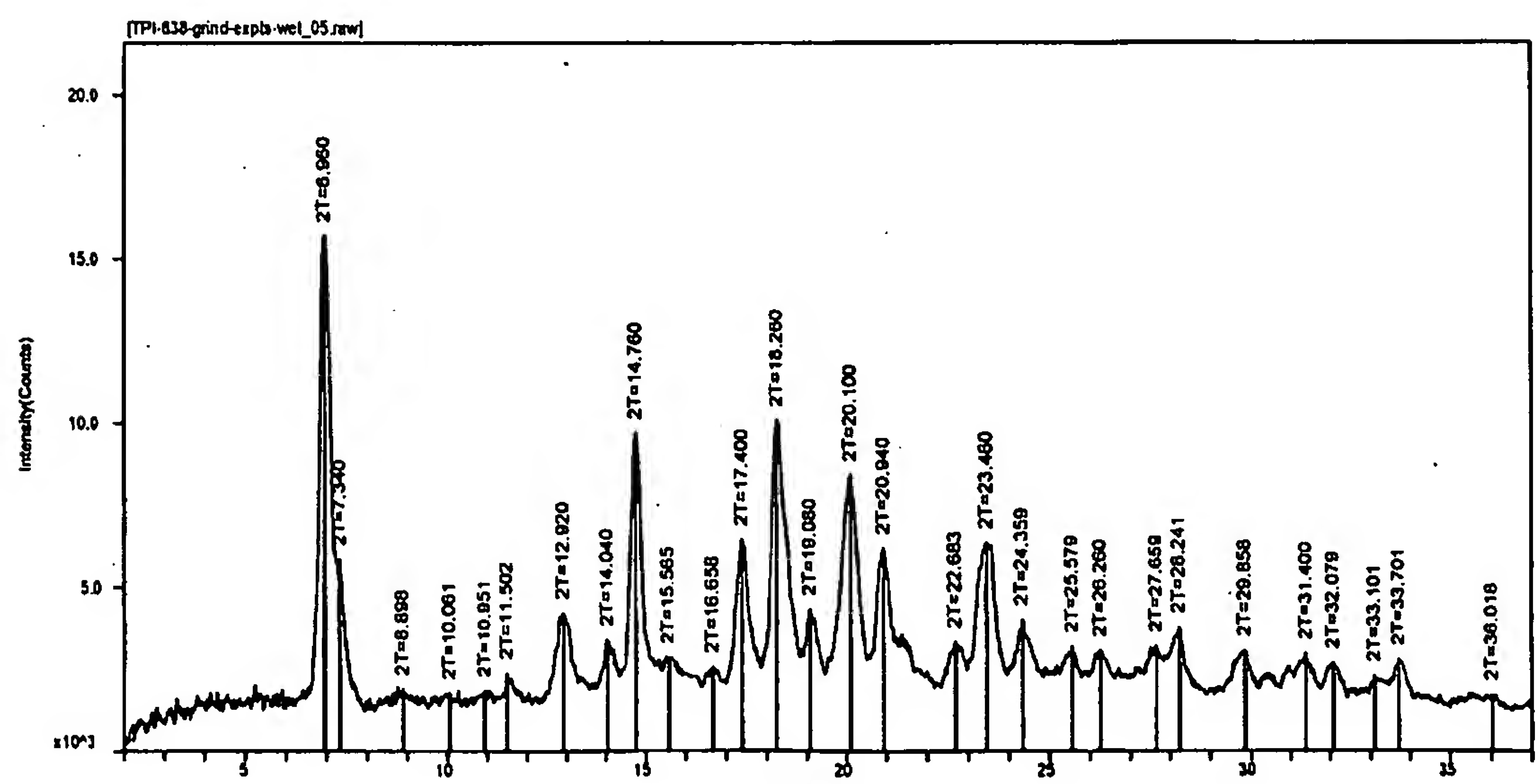


Figure 19

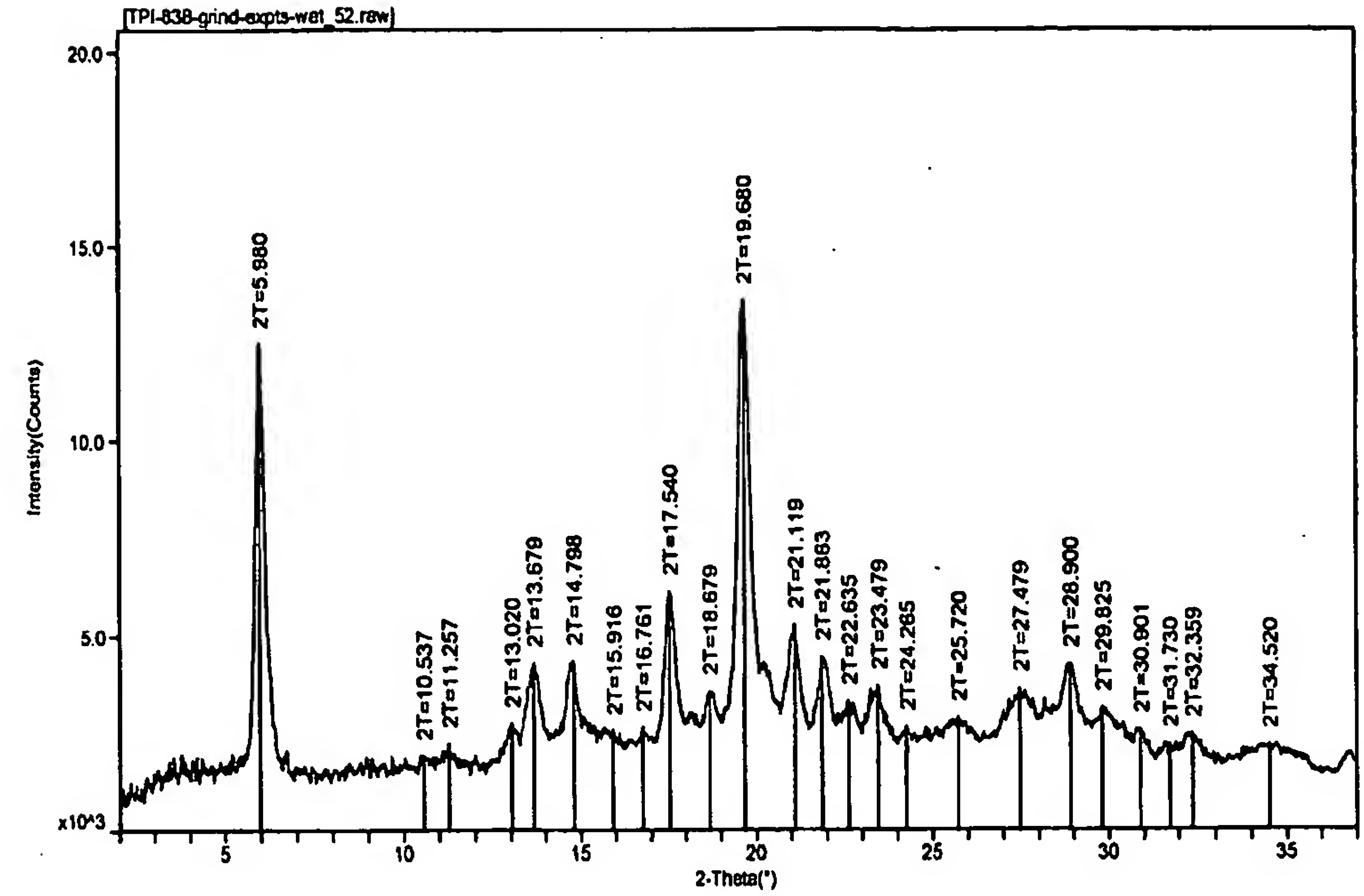


Figure 20

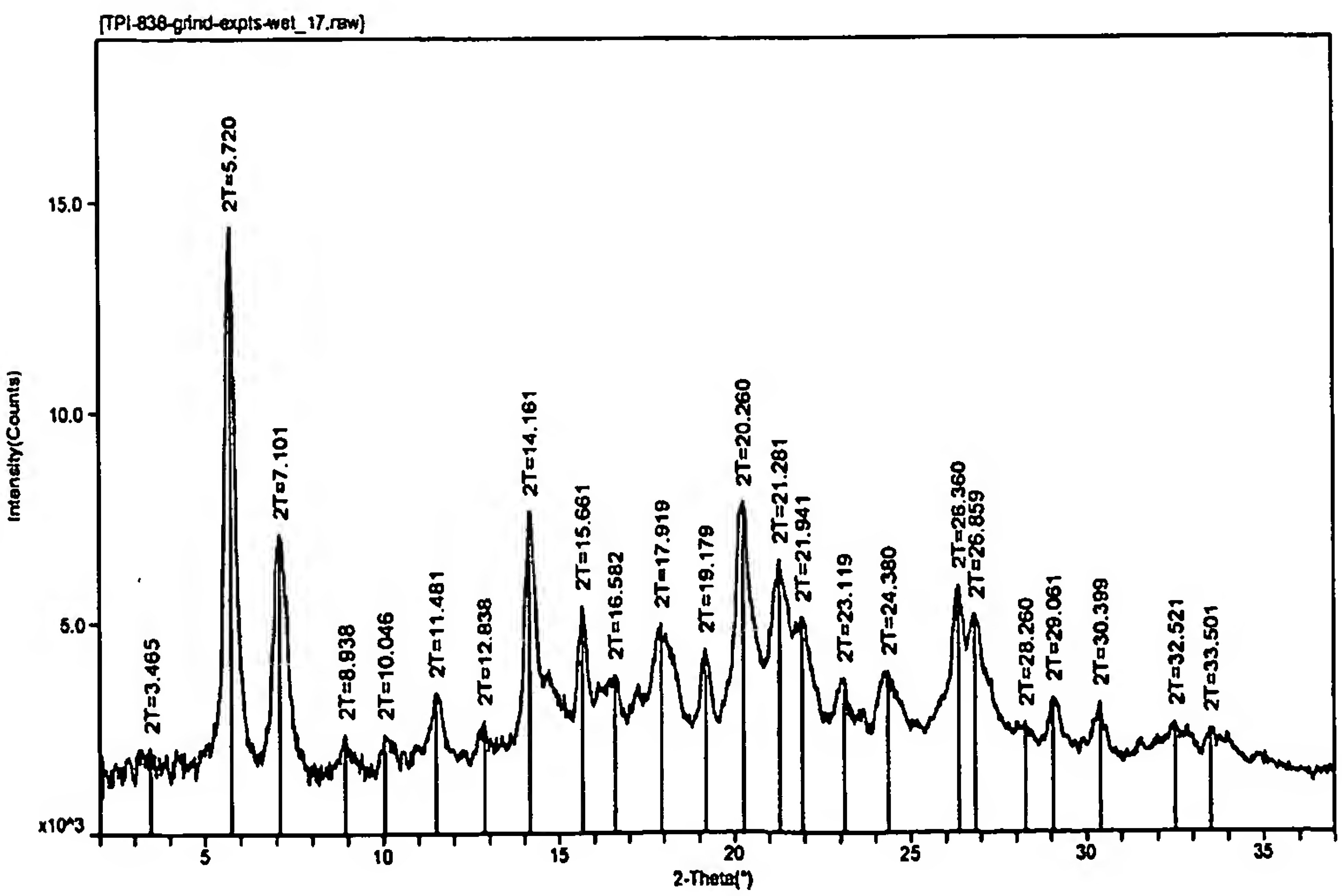


Figure 21

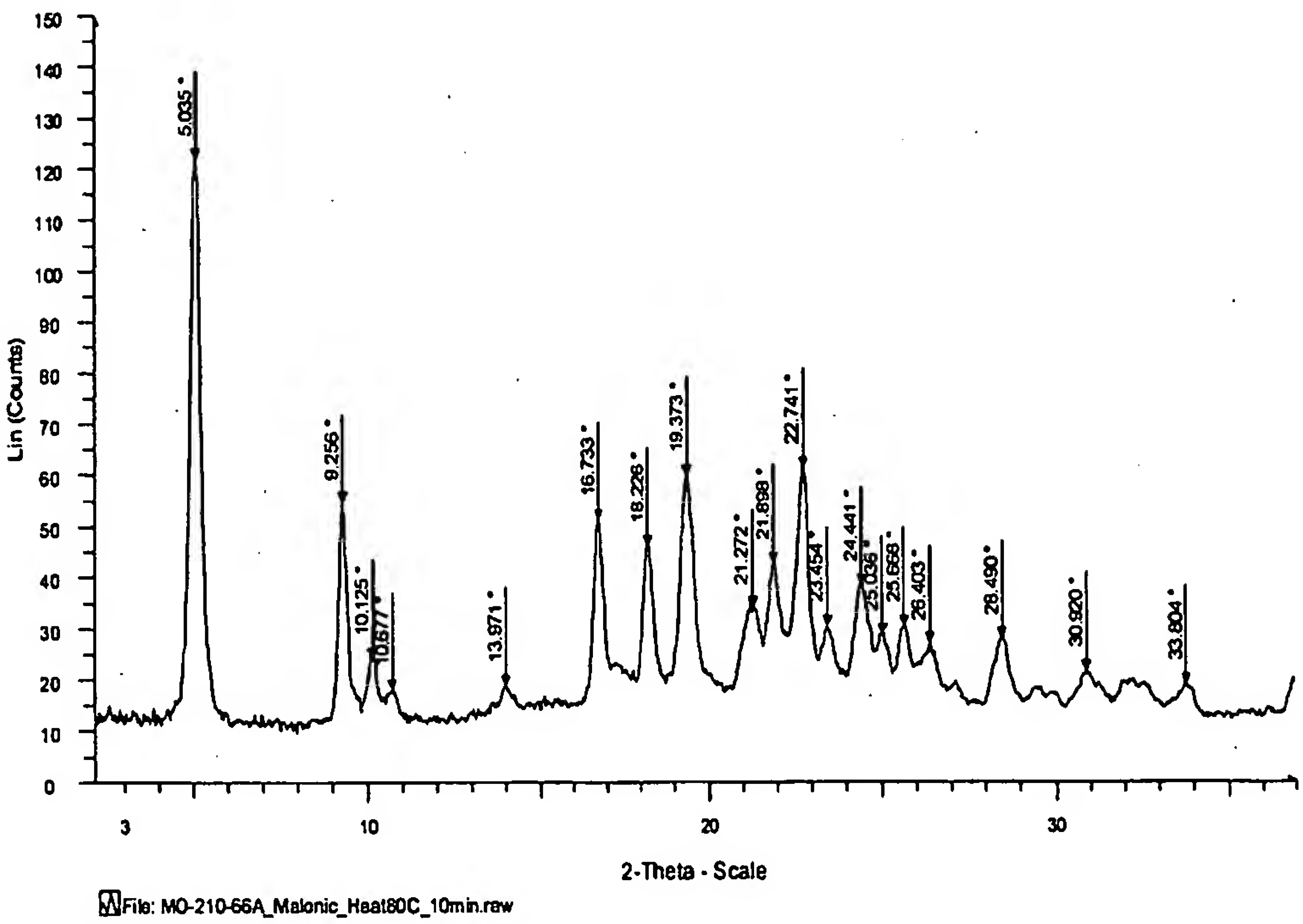


Figure 22

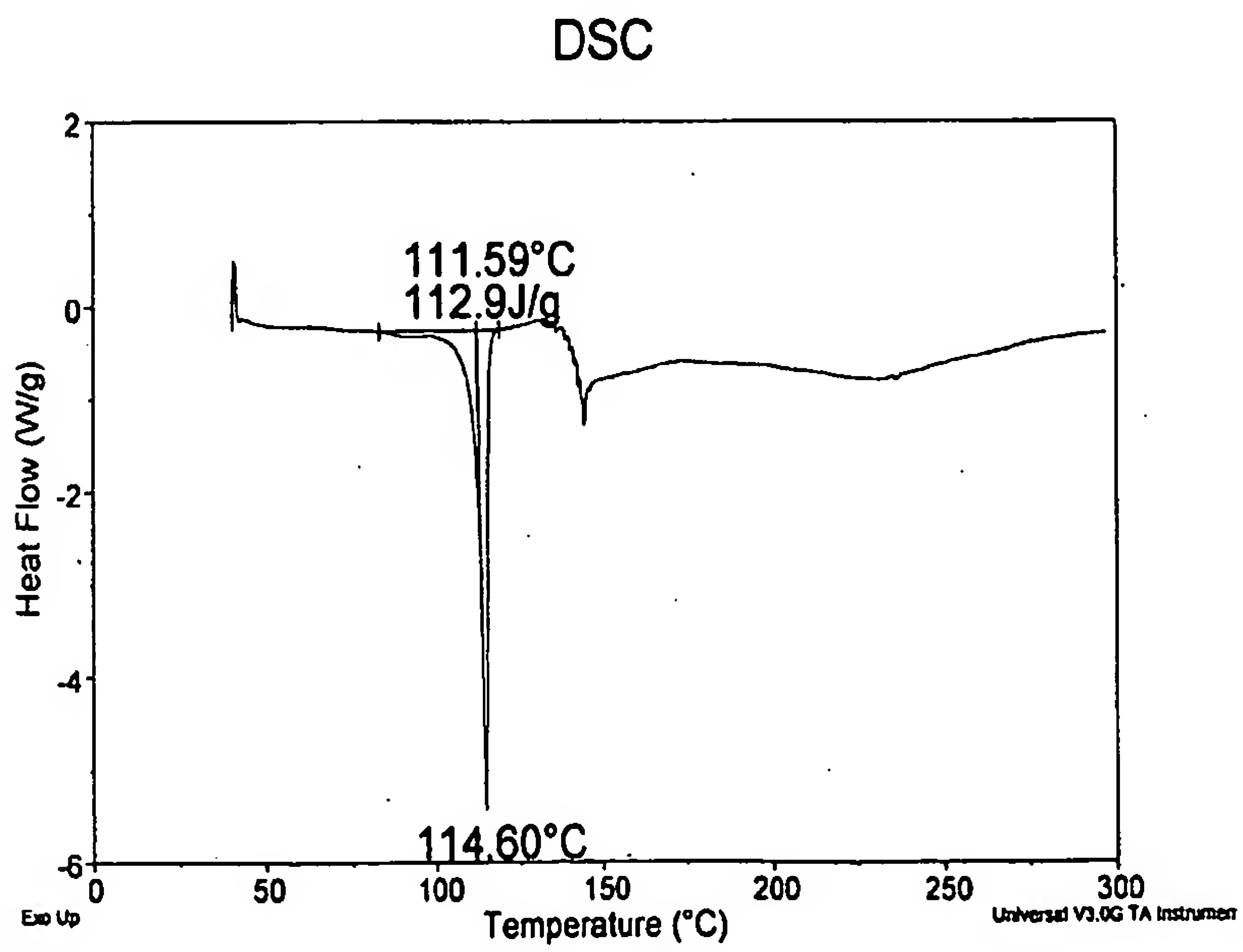


Figure 23

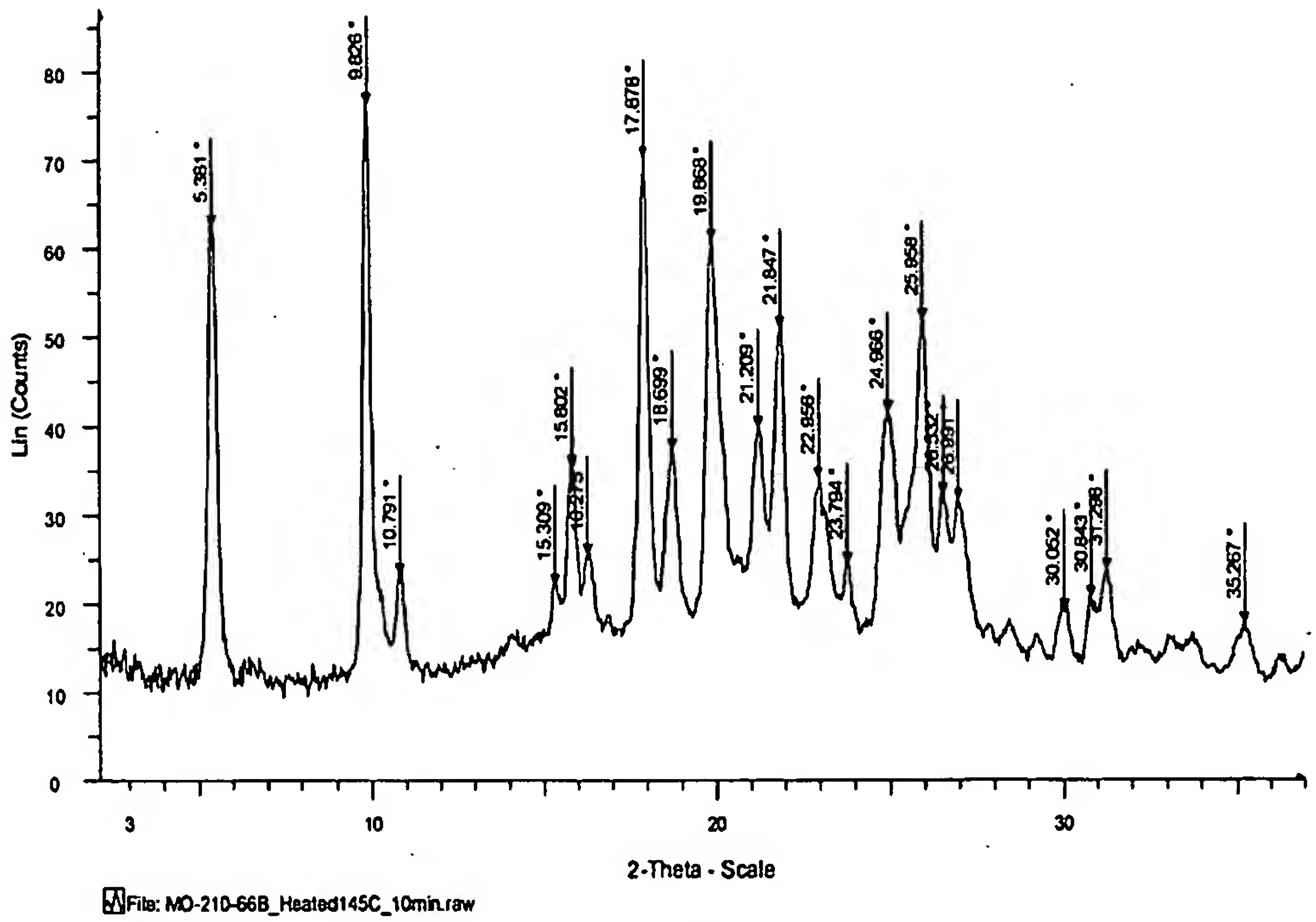


Figure 24

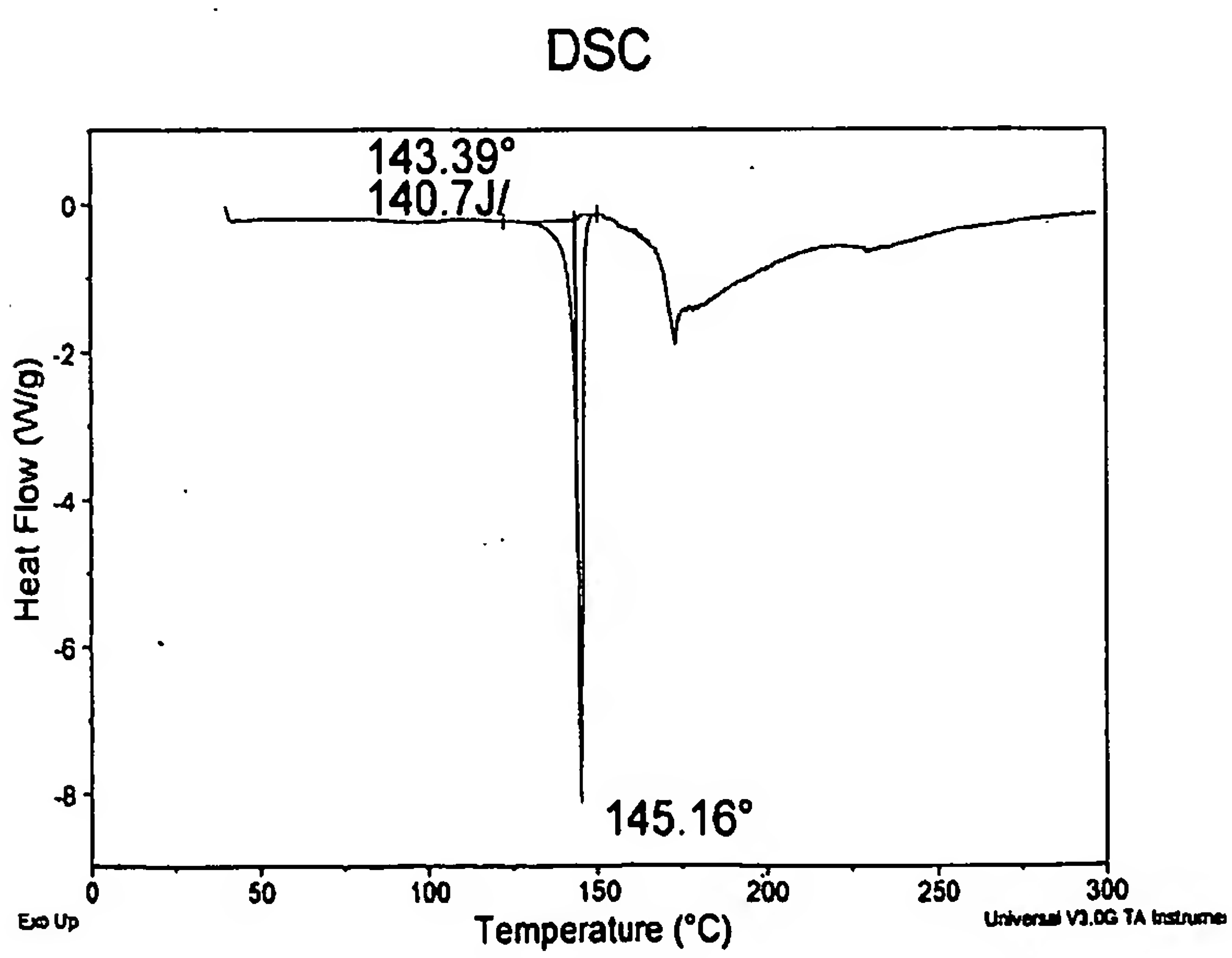


Figure 25

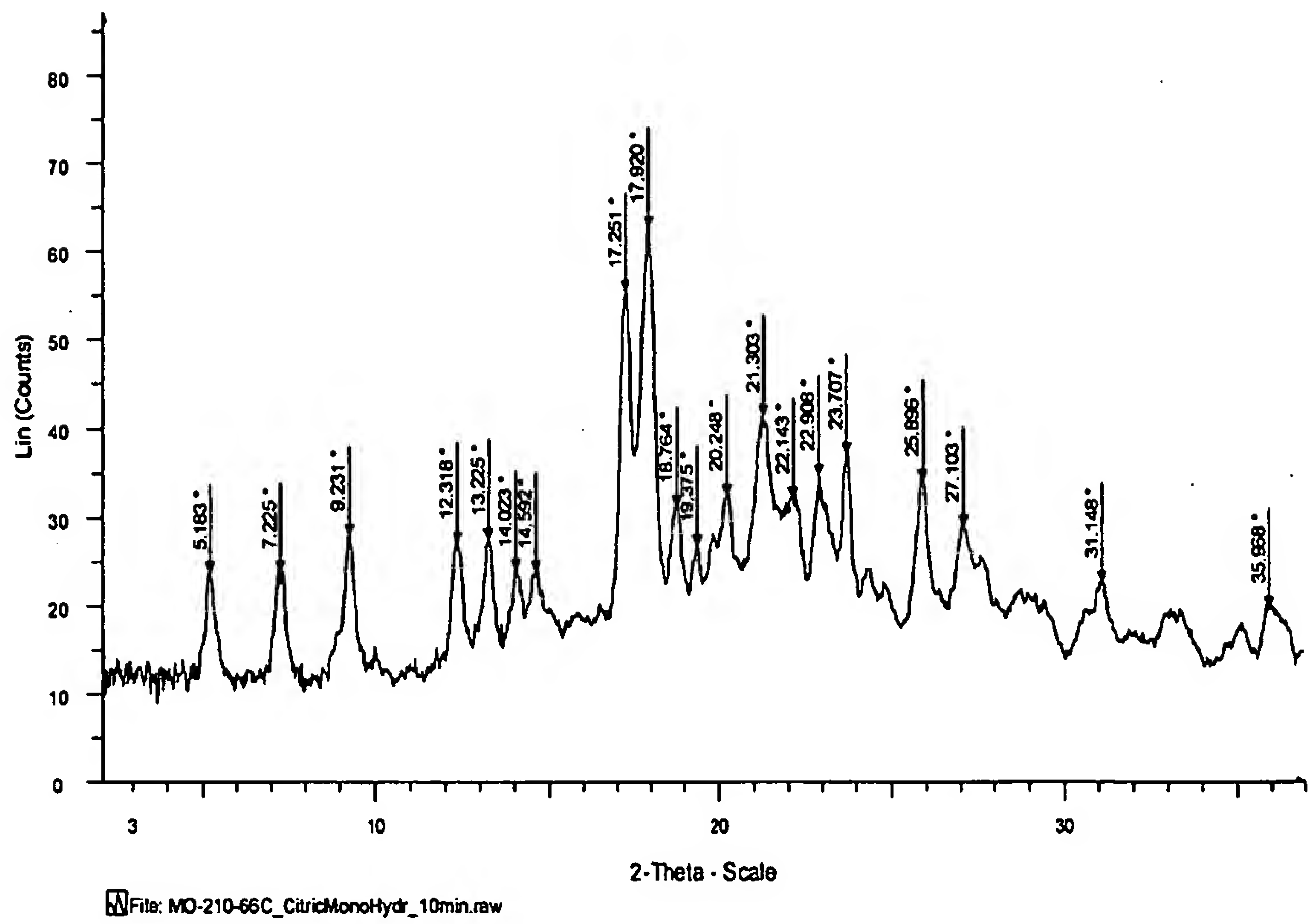


Figure 26

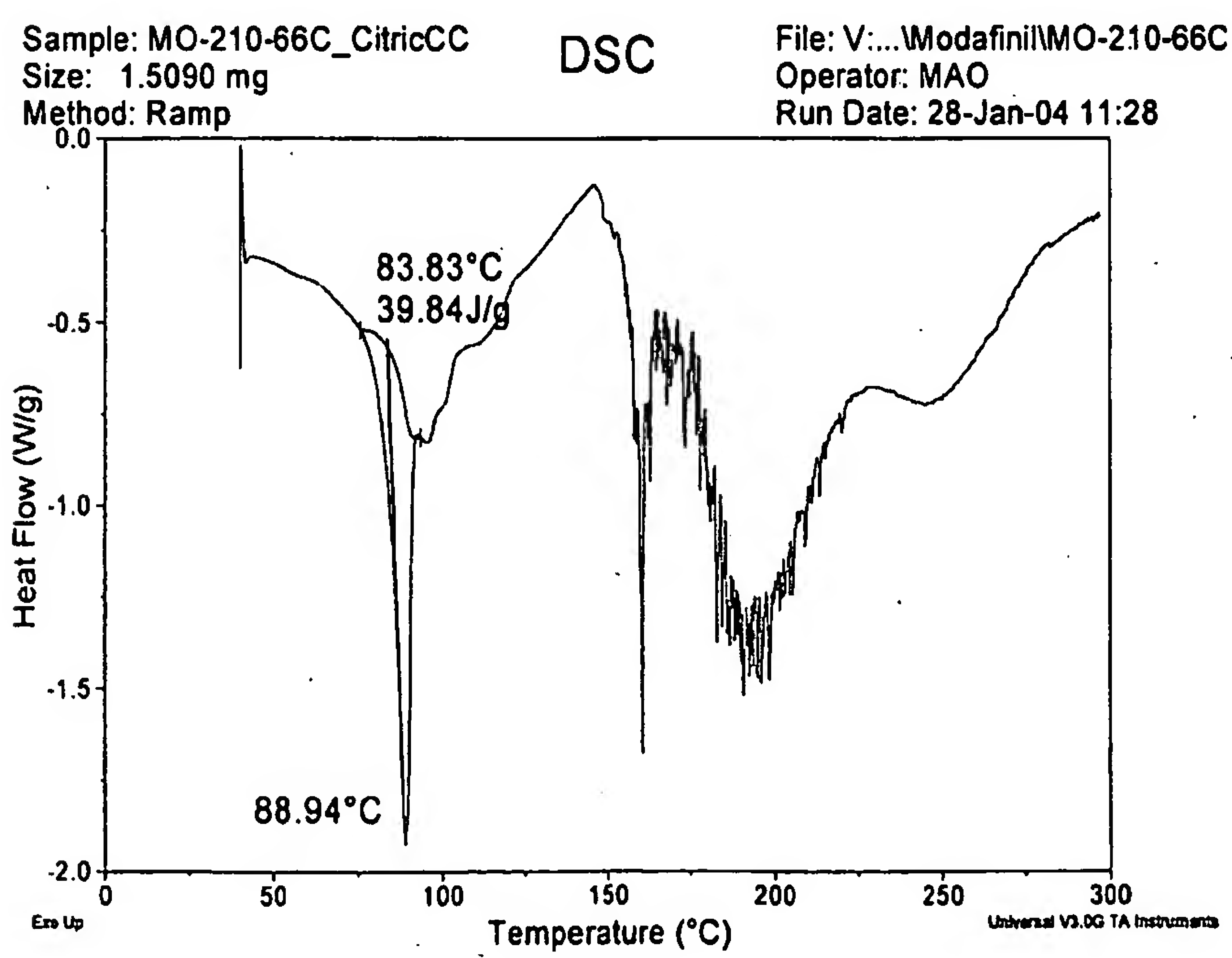


Figure 27

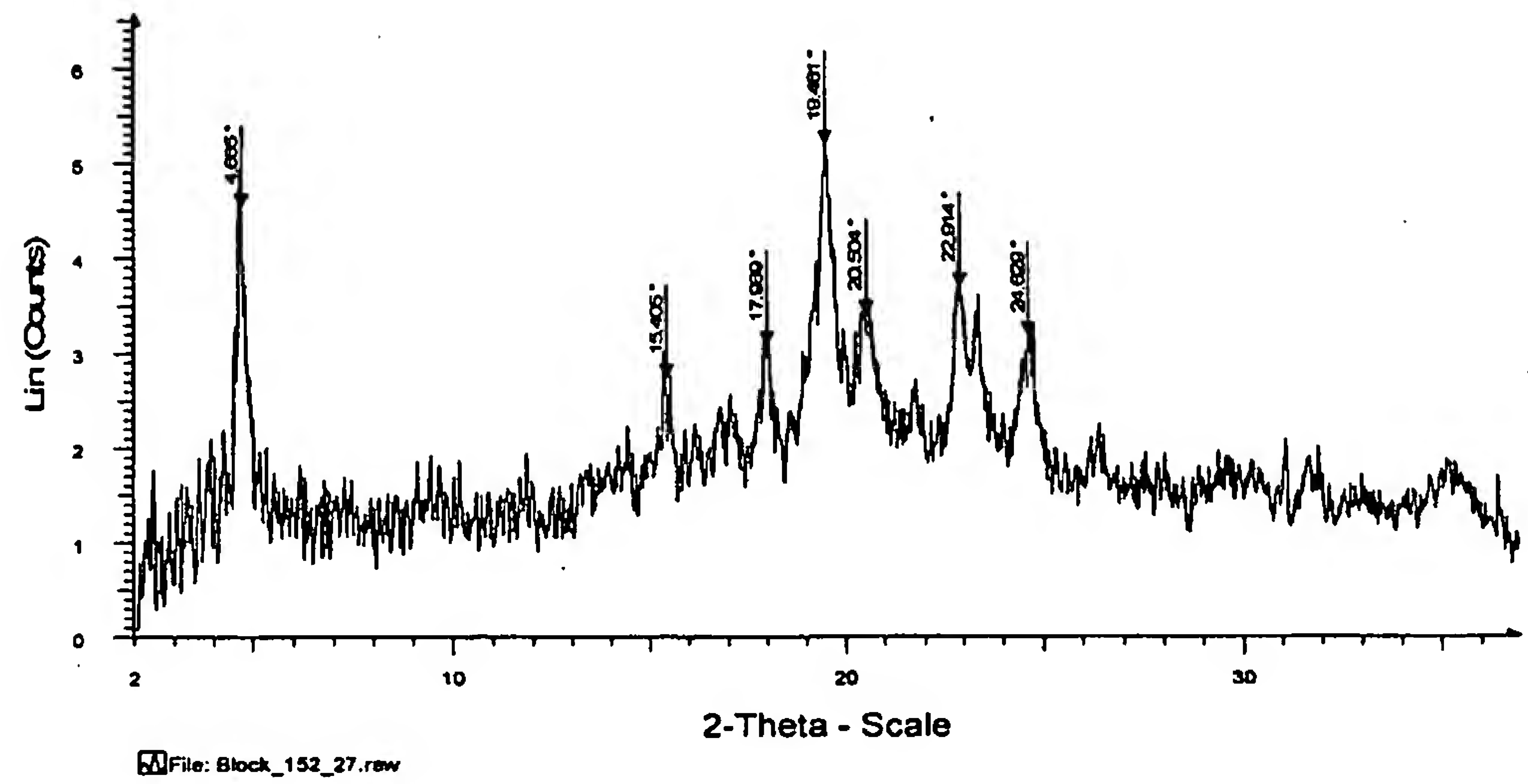


Figure 28

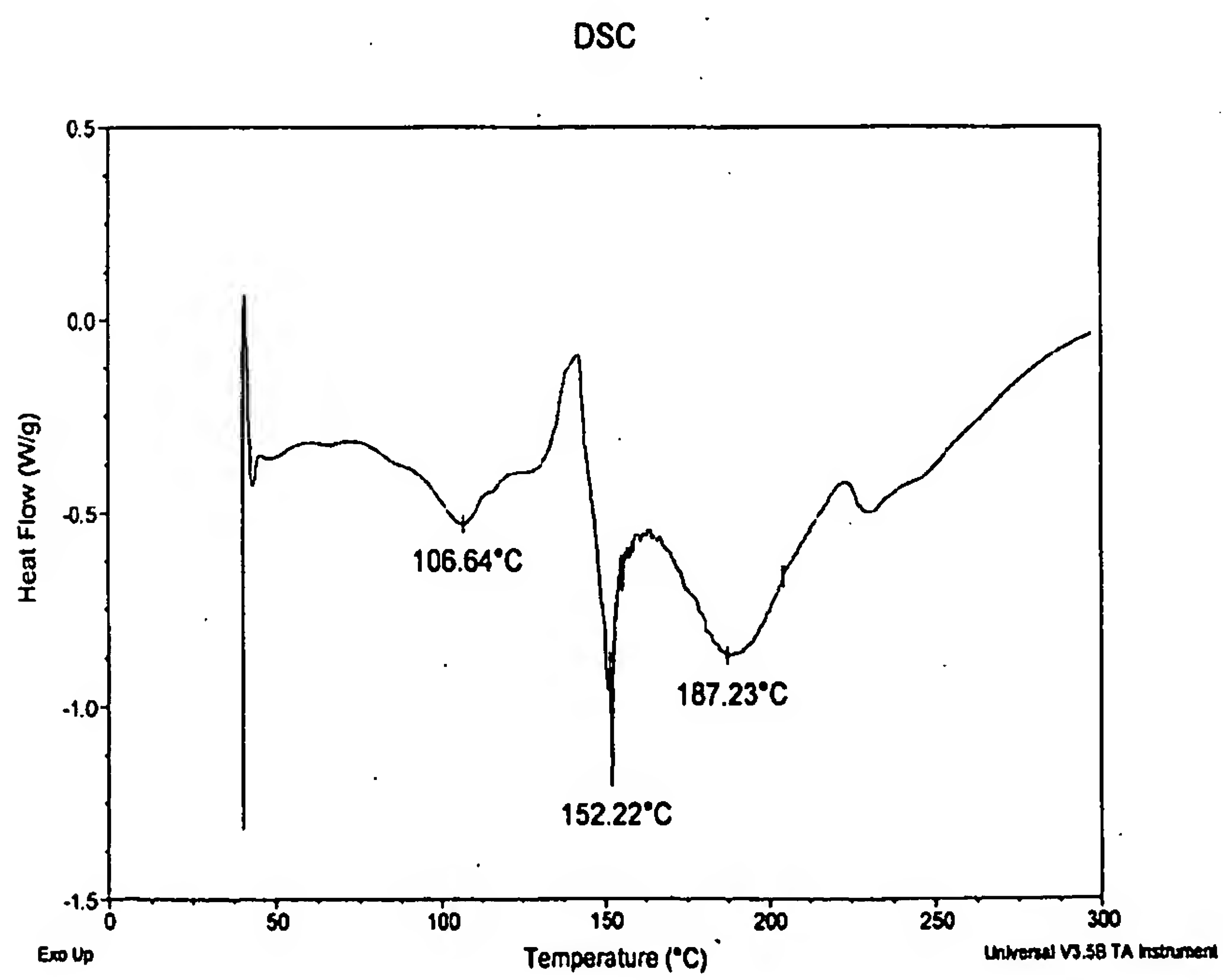


Figure 29

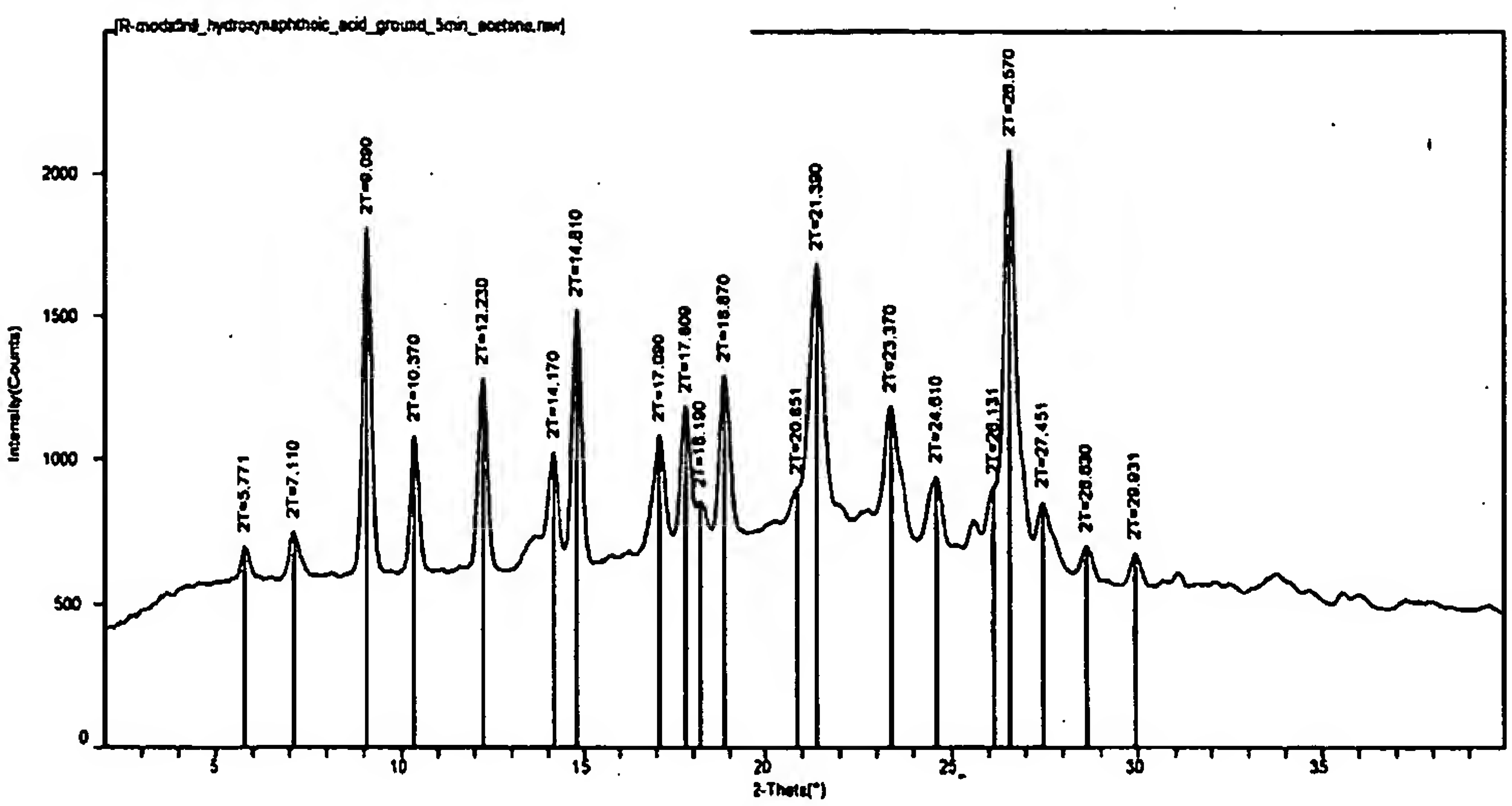


Figure 30

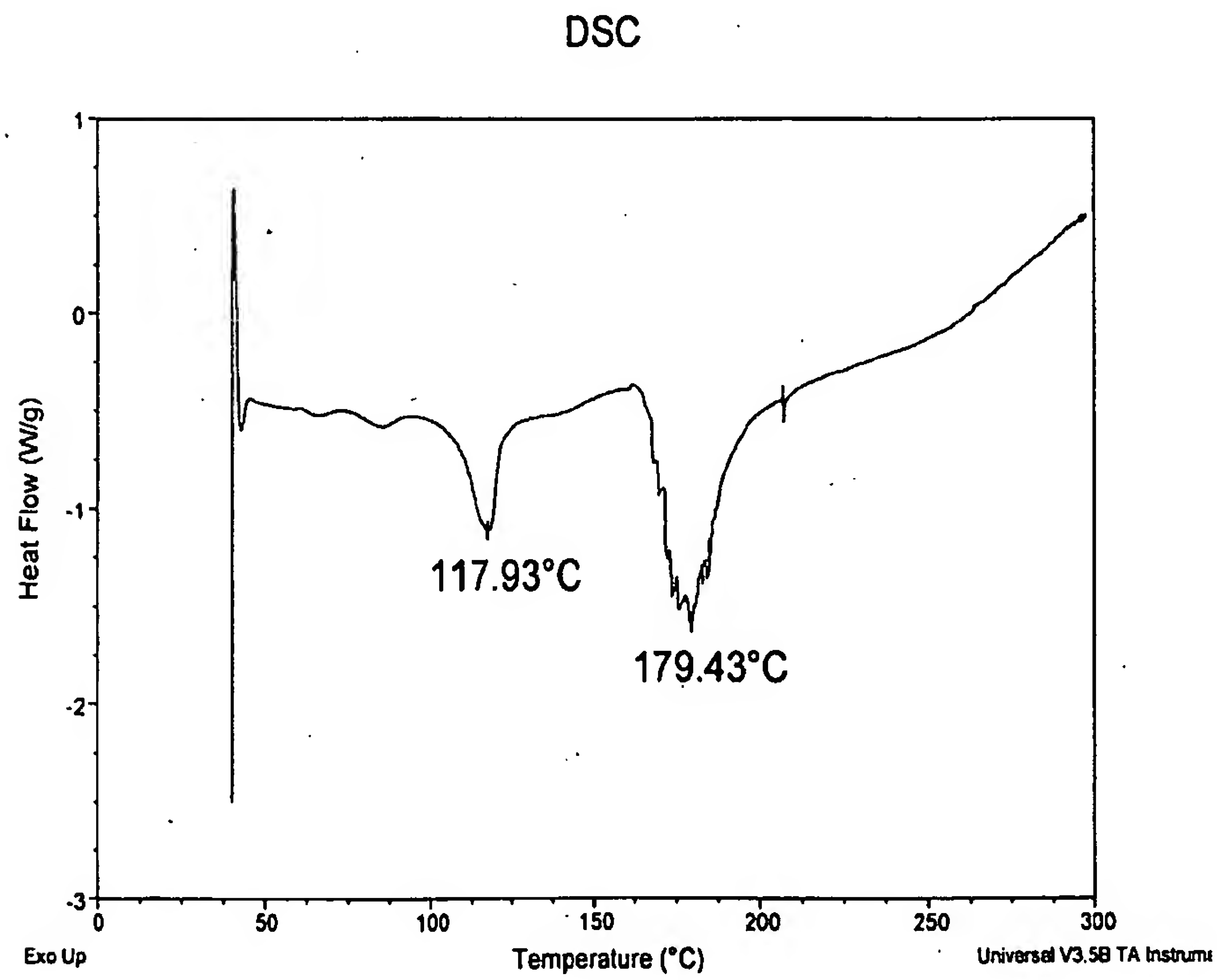


Figure 31

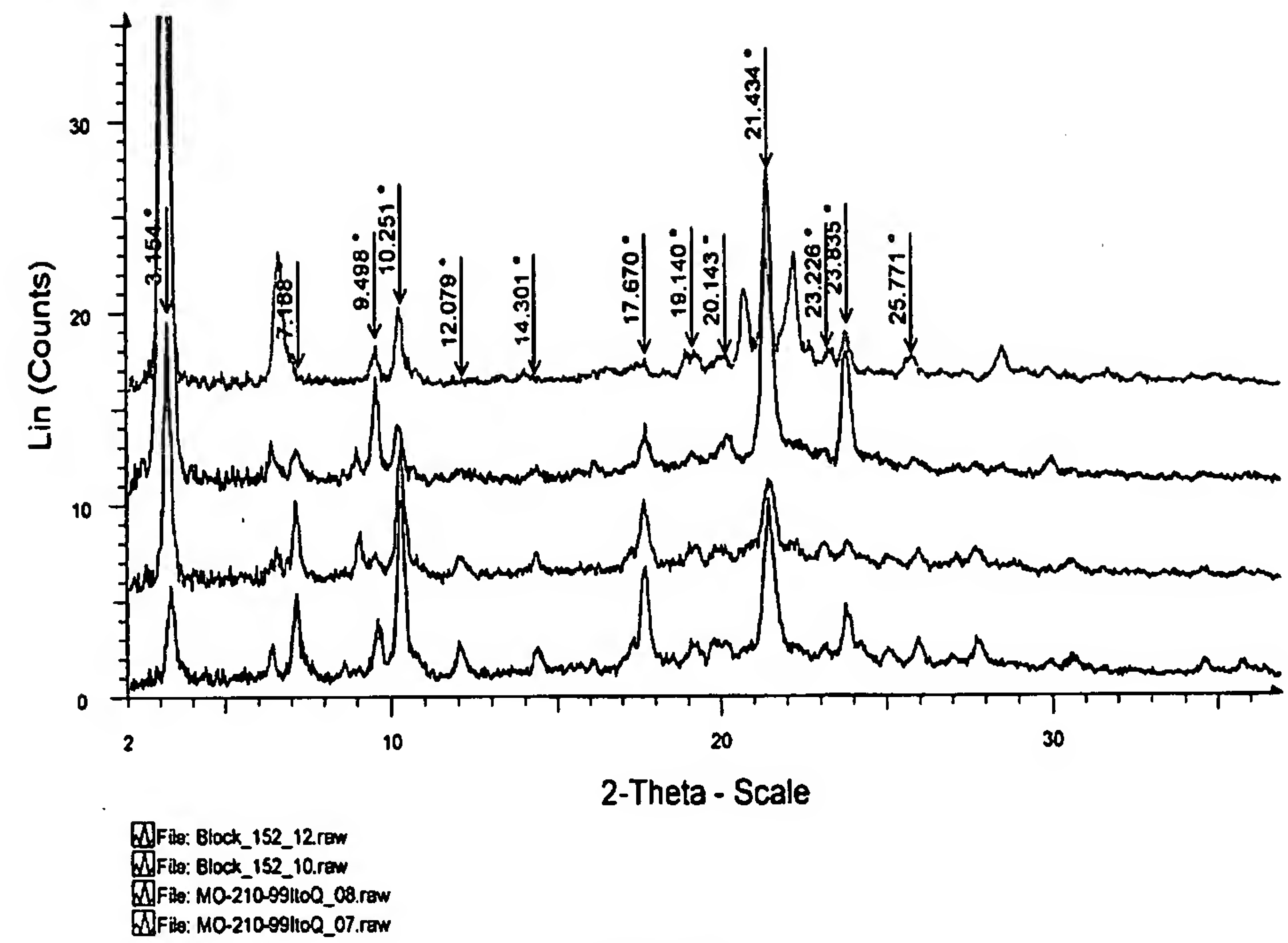


Figure 32

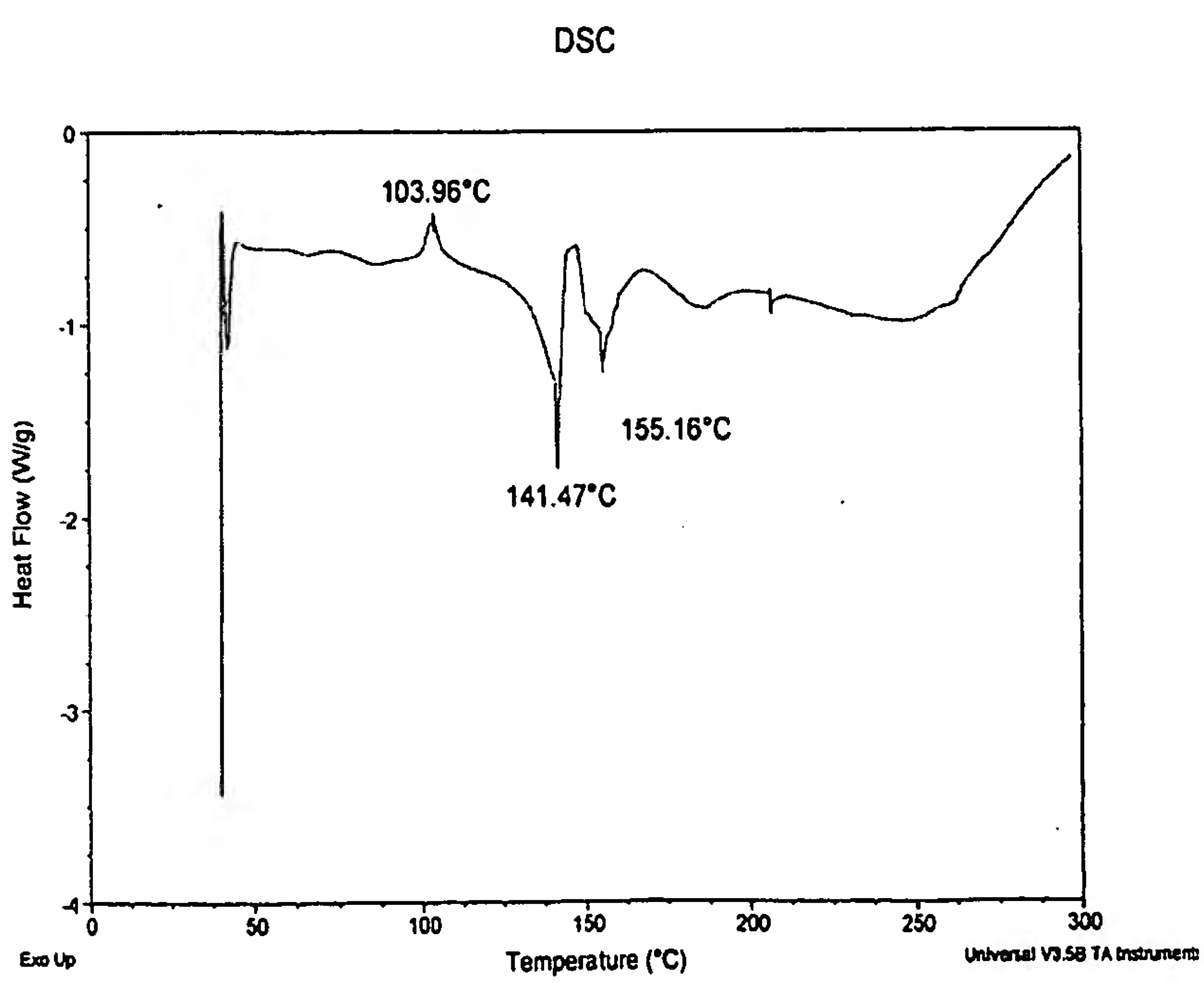
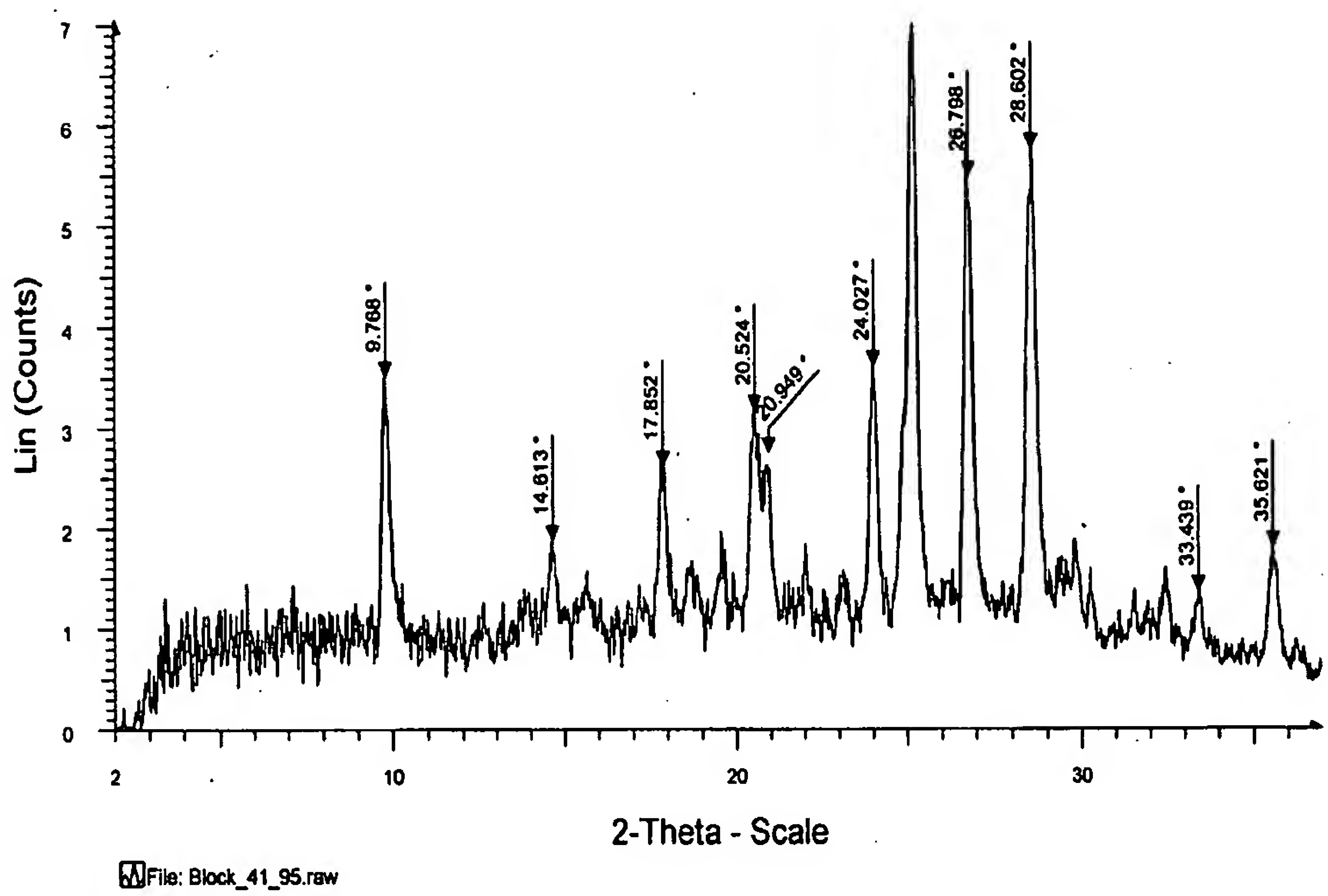


Figure 33



Lin (Counts)
7
6
5
4
3
2
1
0
9.768 °
14.613 °
17.852 °
20.524 °
20.949 °
24.027 °
26.798 °
28.602 °
33.439 °
35.621 °
2
10
20
30
2-Theta - Scale
File: Block_41_95.raw

Figure 34

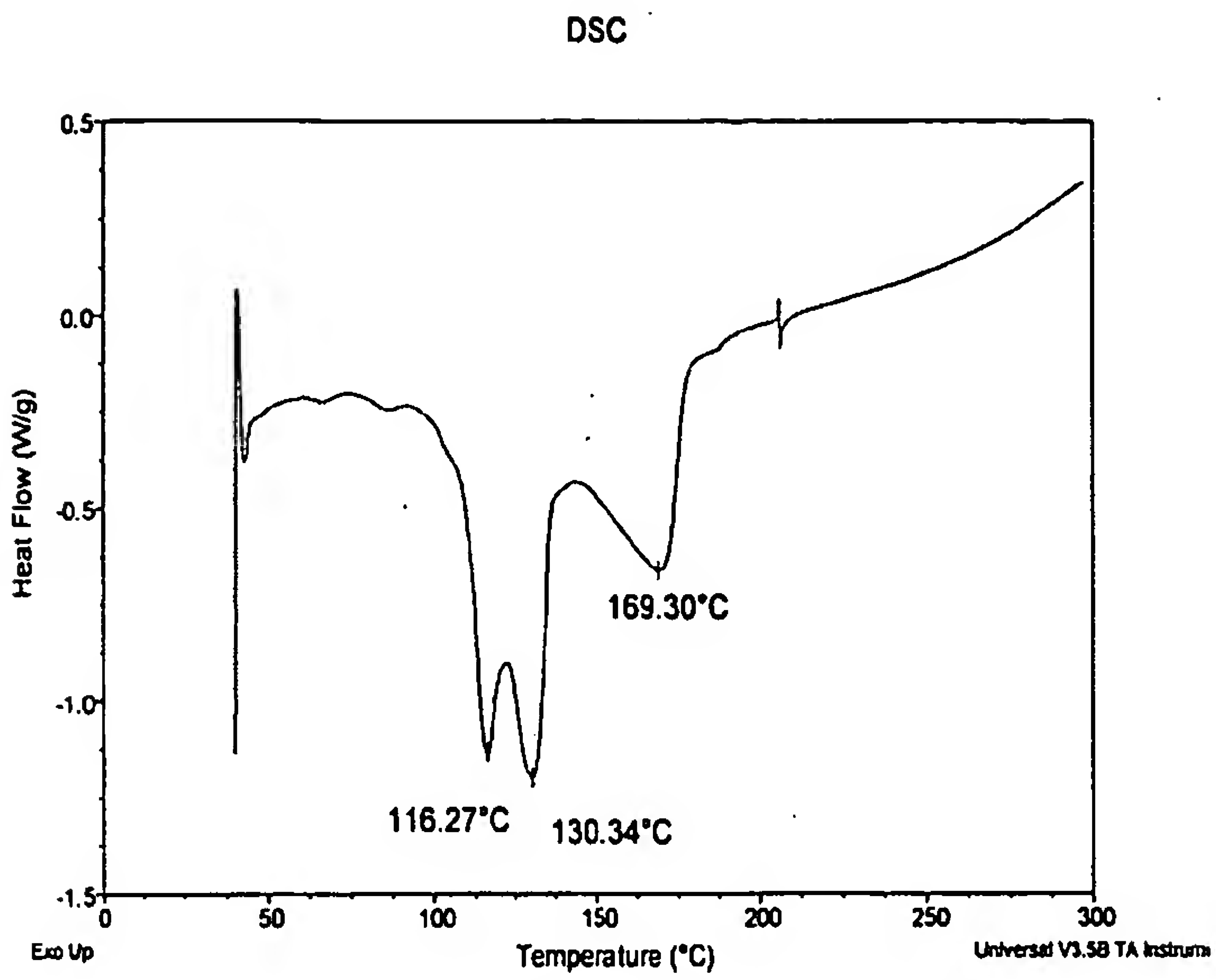
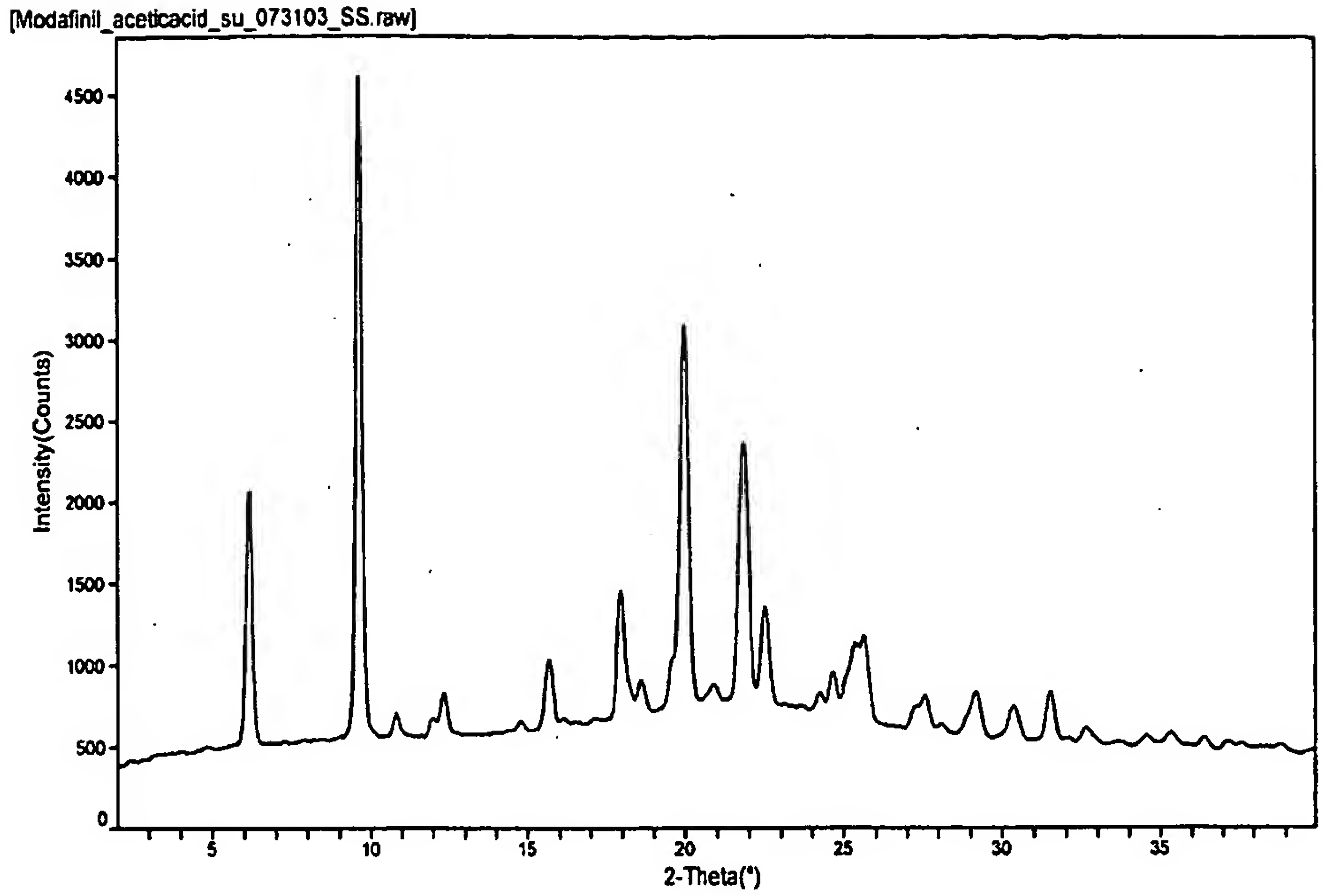

DSC
0.5
0.0
-0.5
-1.0
-1.5
Heat Flow (W/g)
169.30°C
116.27°C
130.34°C
0
50
100
150
200
250
300
Exo Up
Temperature (°C)
Universal V3.5B TA Instrum

Figure 35



2-Theta Degrees
6.169
9.629
10.810
11.990
12.349
14.771
15.690
17.970
18.610
19.990
20.929
21.830
22.510
24.248
24.669
25.611
27.569
28.093
29.190
30.390

Figure 36

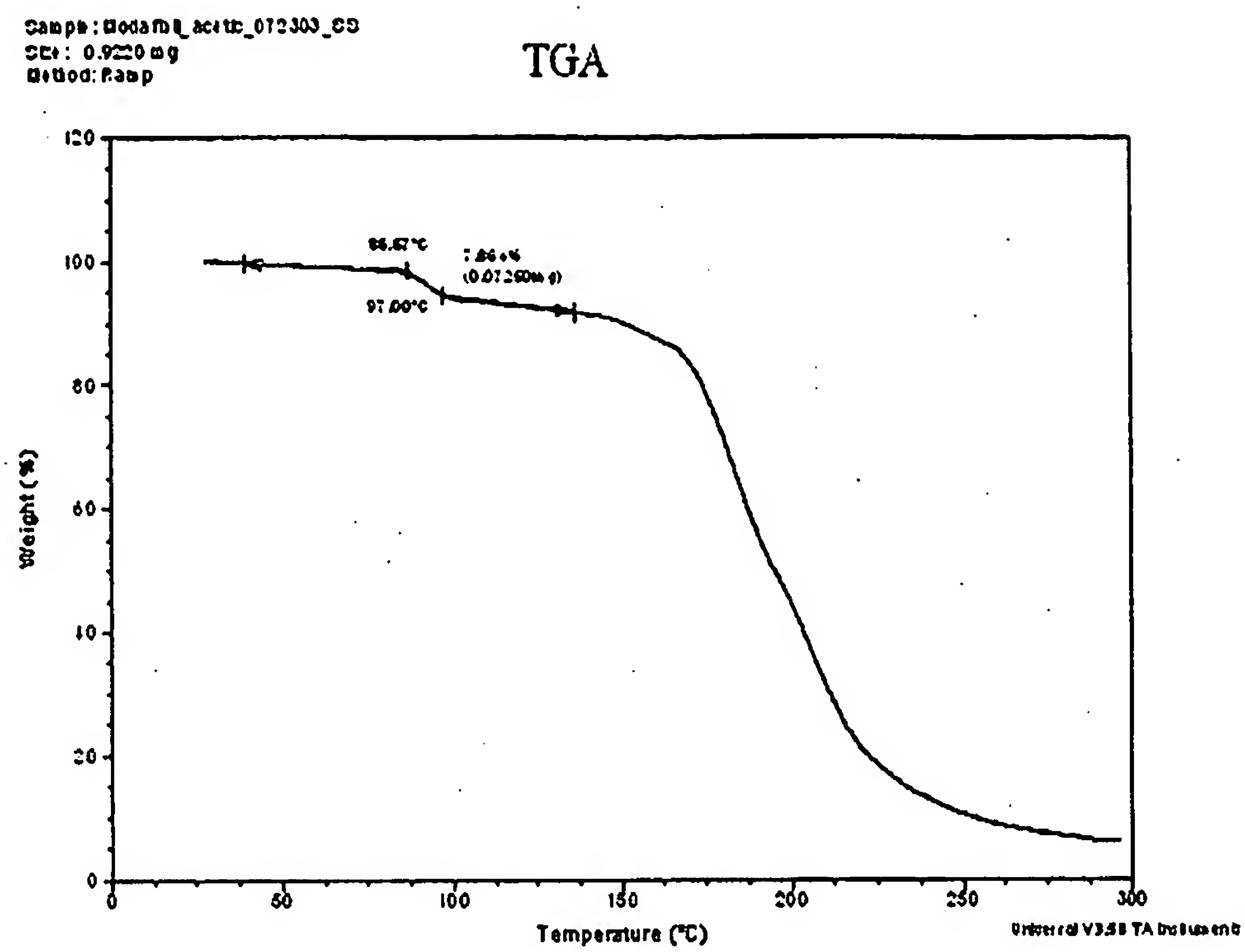

TGA
97.00°C
Weight (%)
Temperature (°C)
0
20
40
60
80
100
120
0
50
100
150
200
250
300

Figure 37

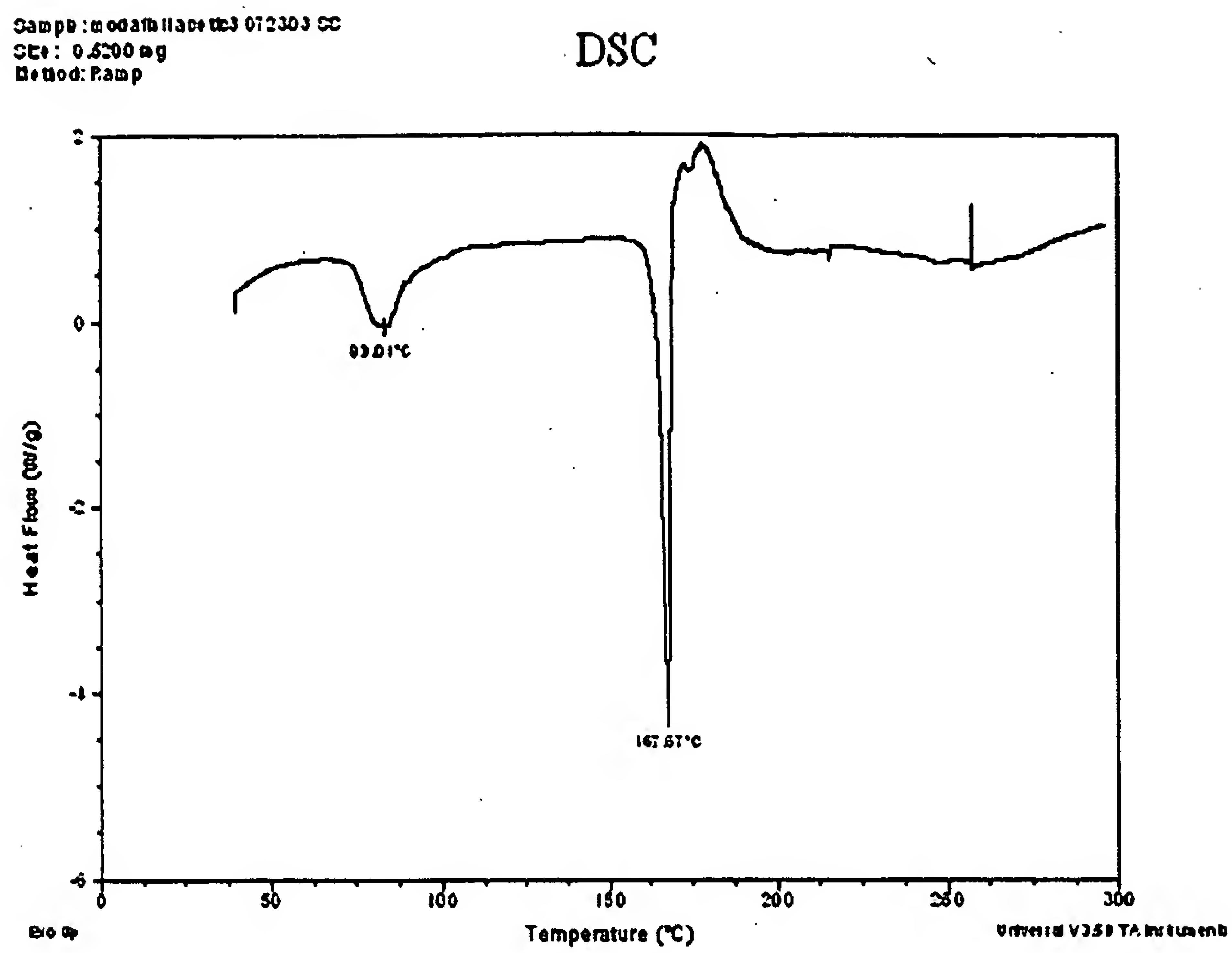
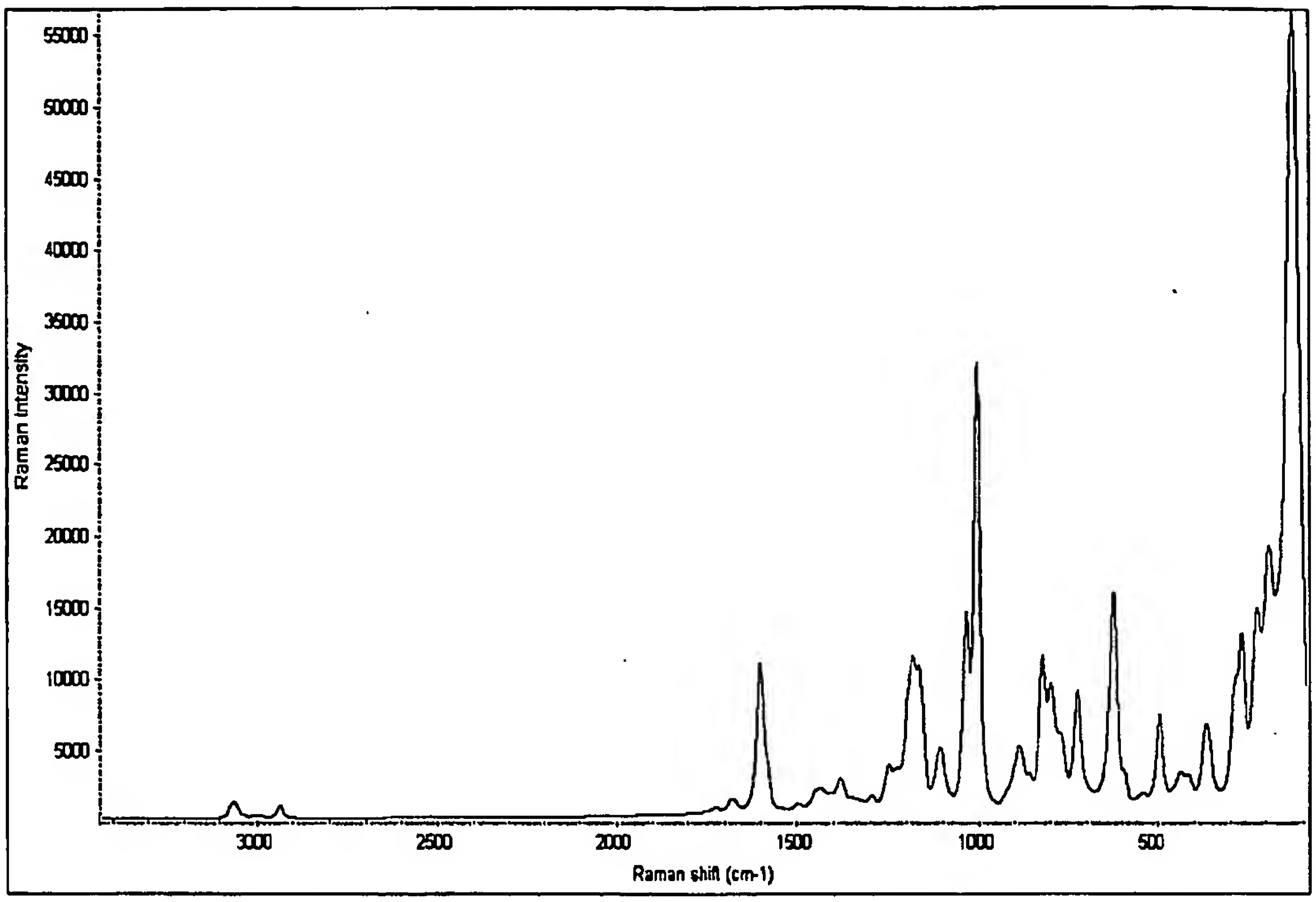

Sample: modafinil acetic3 072303 SC
Size: 0.6200 mg
Method: Ramp
DSC
Heat Flow (W/g)
83.01°C
167.67°C
Temperature (°C)
Universal V3.5B TA Instruments

Figure 38



Position:	124.38	Intensity:	56488.199
Position:	1003.39	Intensity:	32065.602
Position:	190.78	Intensity:	19242.451
Position:	624.92	Intensity:	16043.604
Position:	1032.16	Intensity:	14613.689
Position:	267.46	Intensity:	13128.612
Position:	822.14	Intensity:	11636.112
Position:	1181.06	Intensity:	11607.680
Position:	1601.13	Intensity:	11005.503
Position:	725.91	Intensity:	9152.309
Position:	494.61	Intensity:	7458.328
Position:	362.59	Intensity:	6747.720
Position:	887.40	Intensity:	5256.710
Position:	1106.67	Intensity:	5119.203

Figure 39

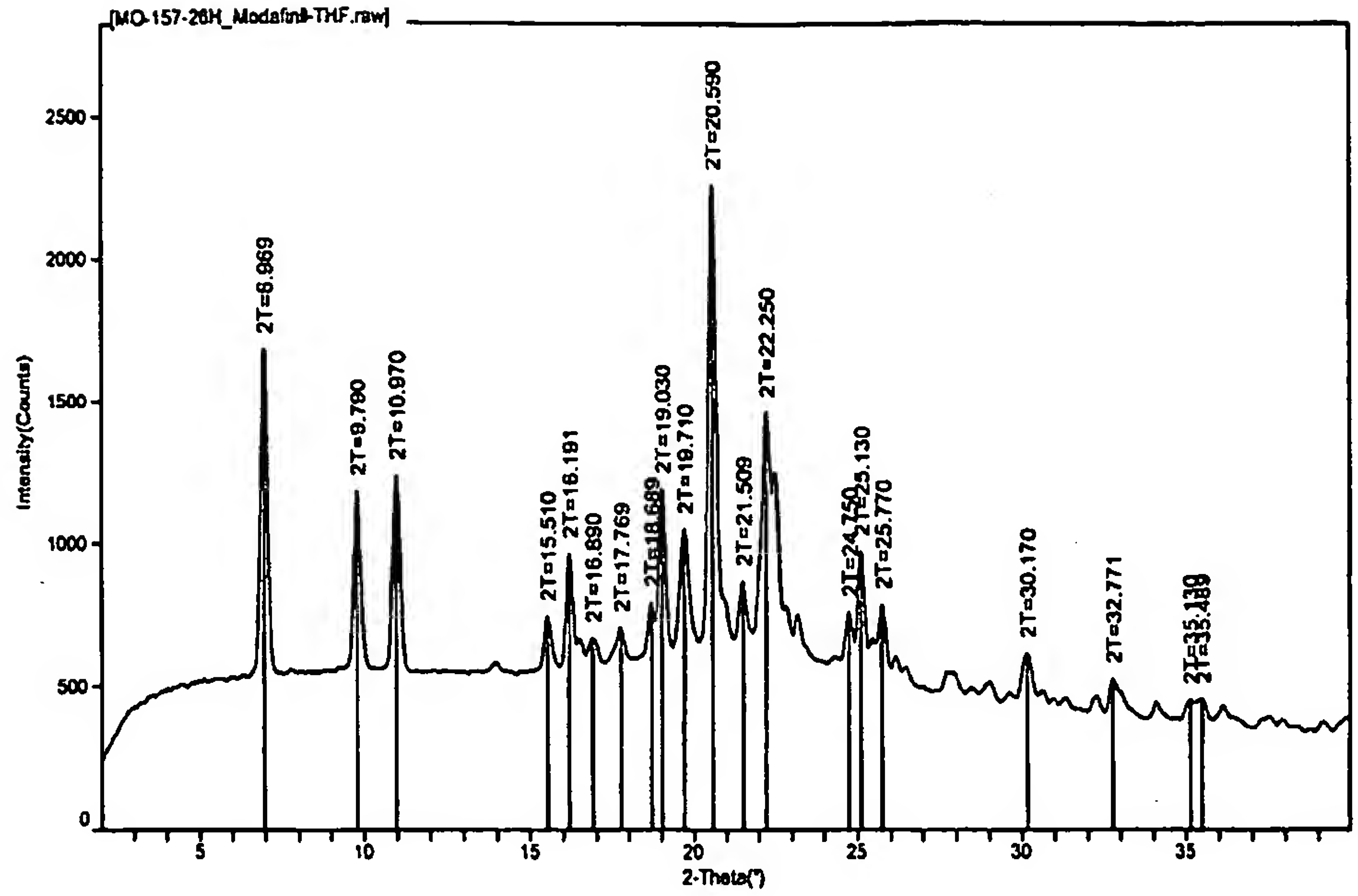


Figure 40

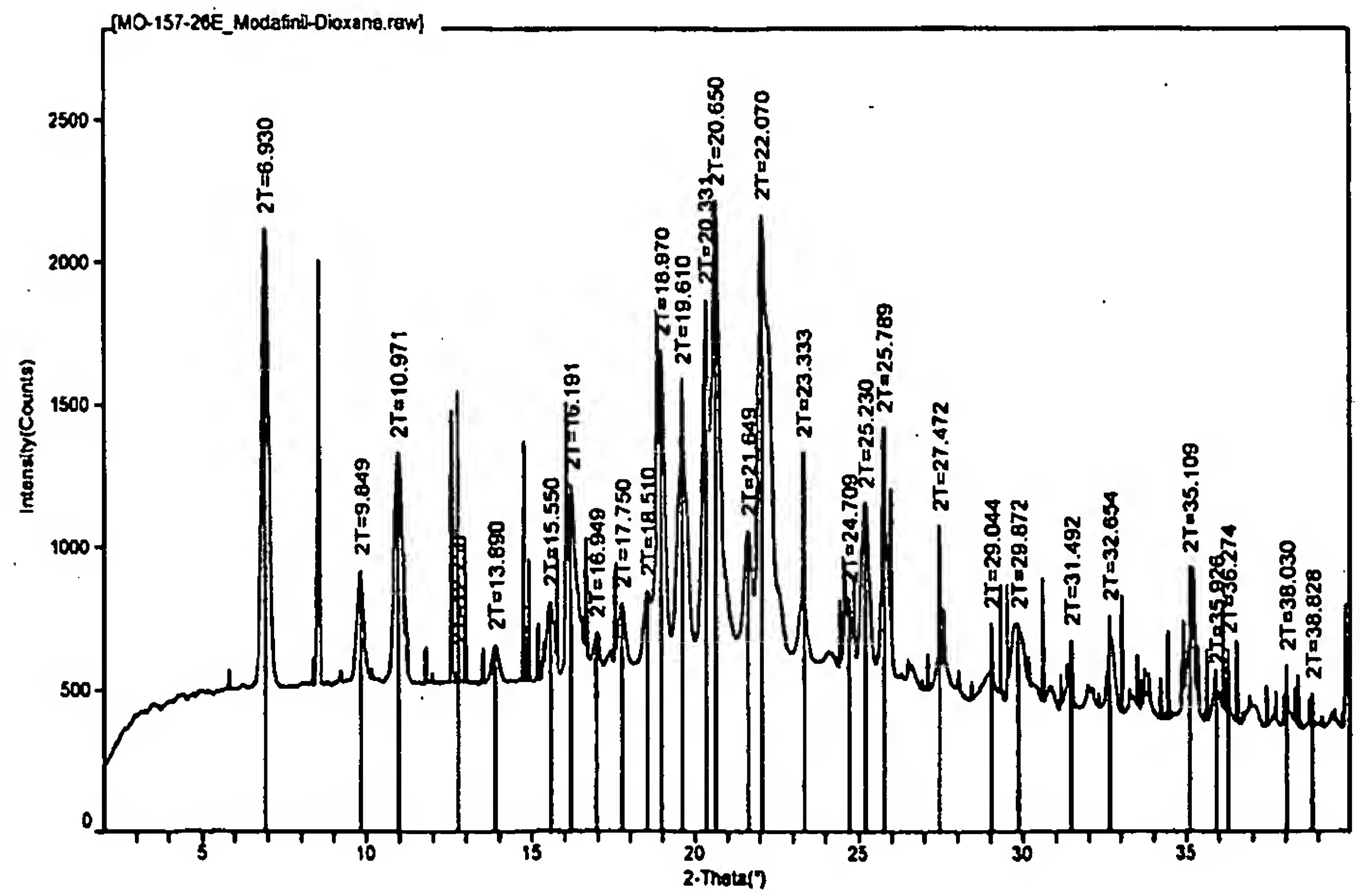


Figure 41

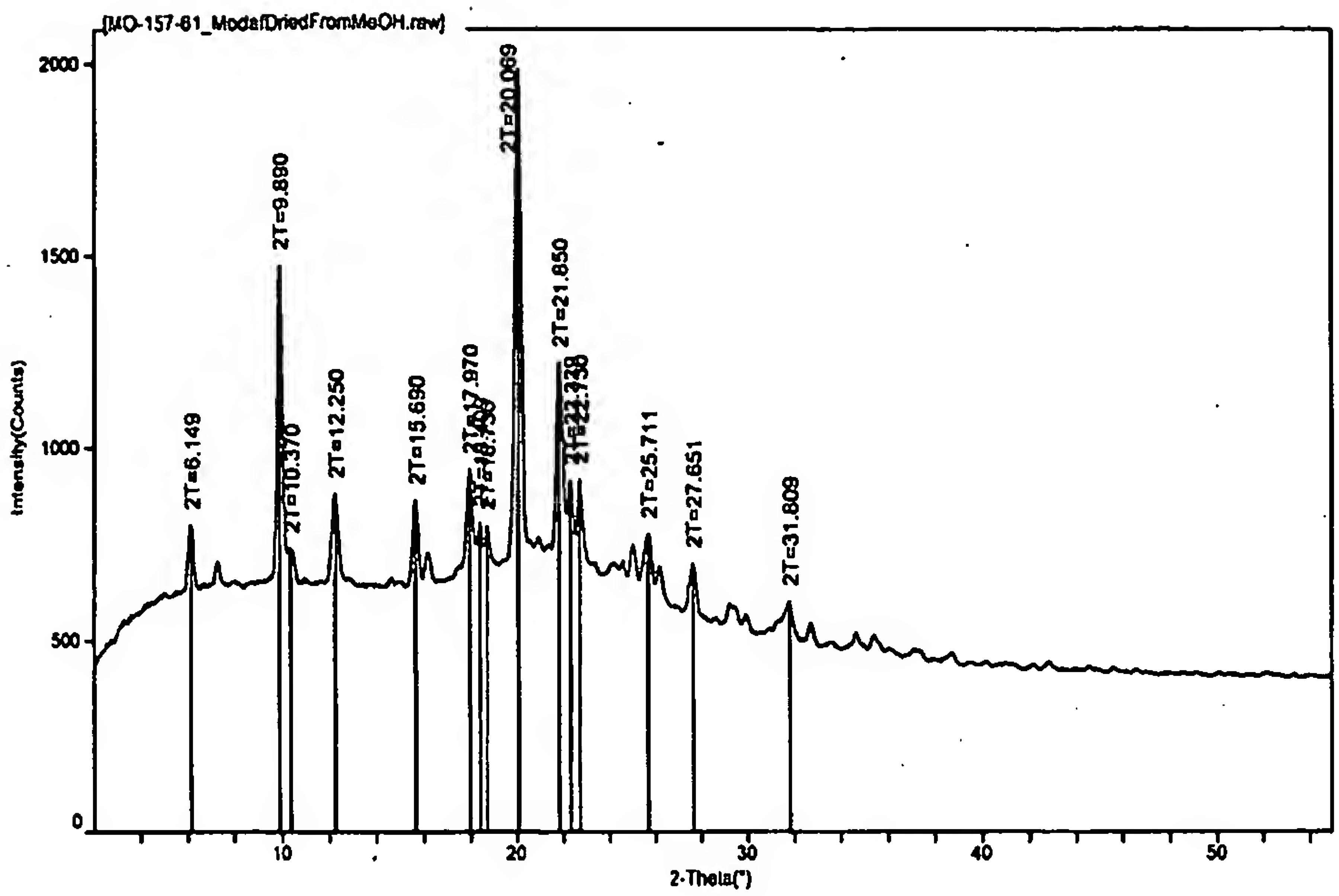


Figure 42

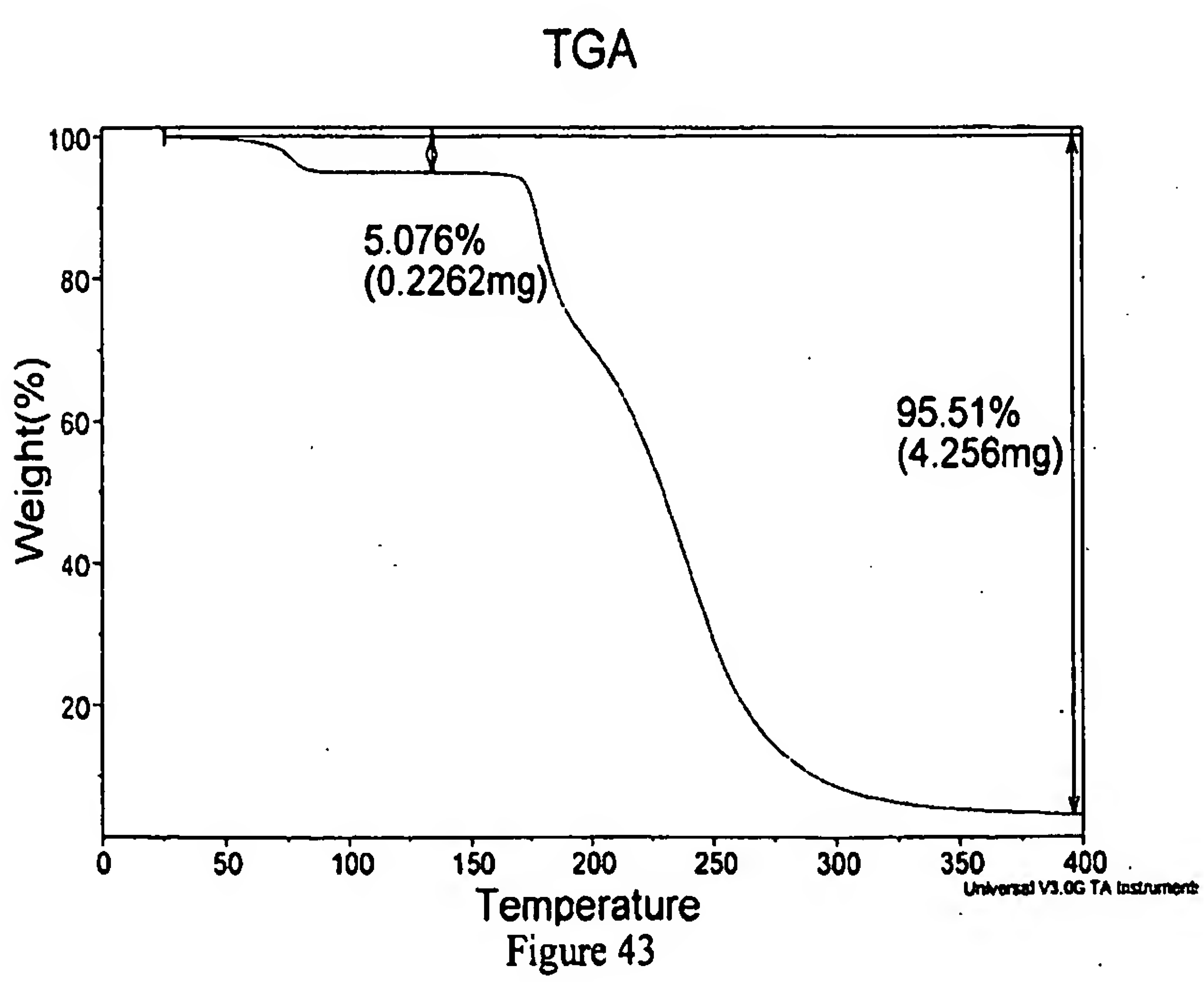


Figure 43

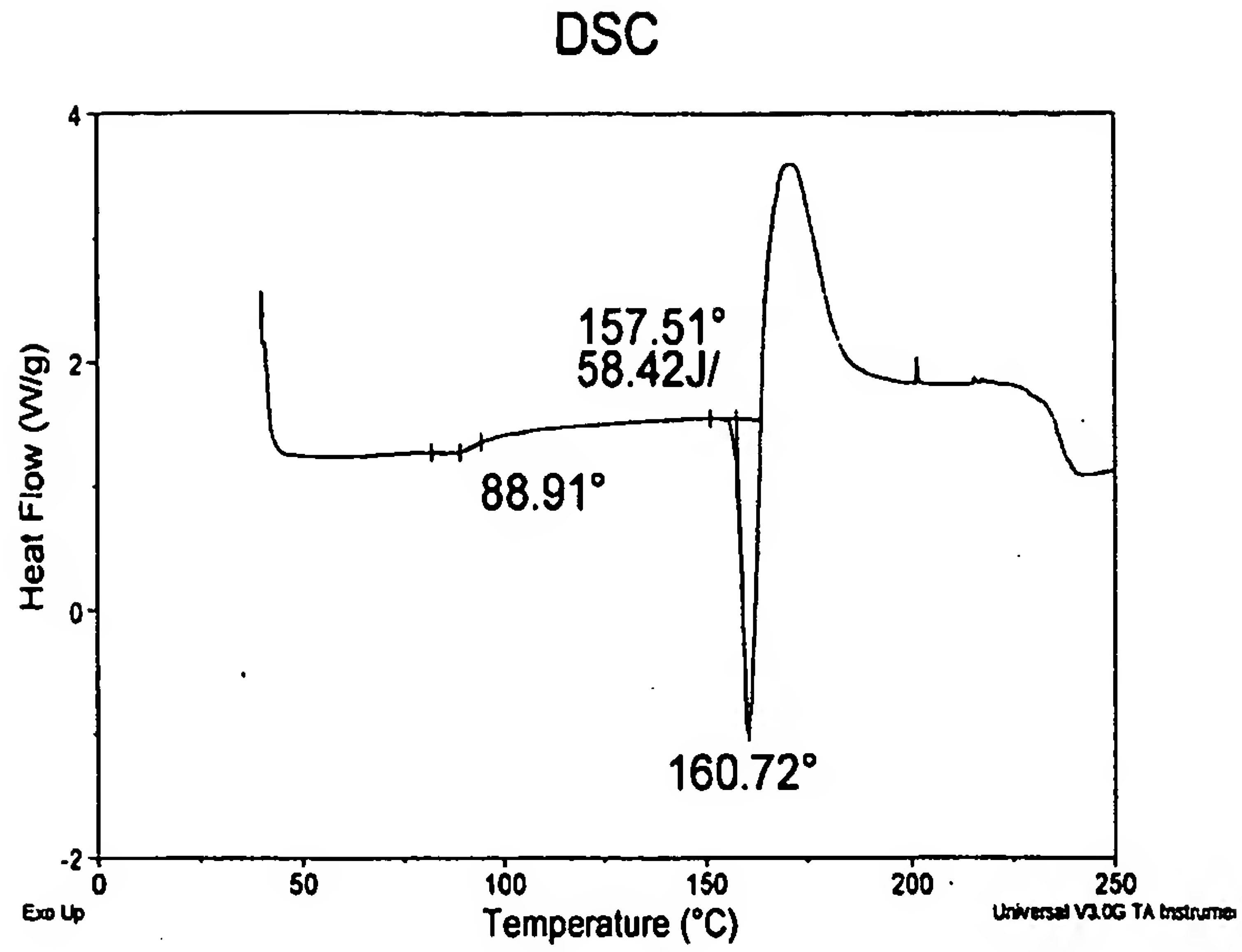


Figure 44

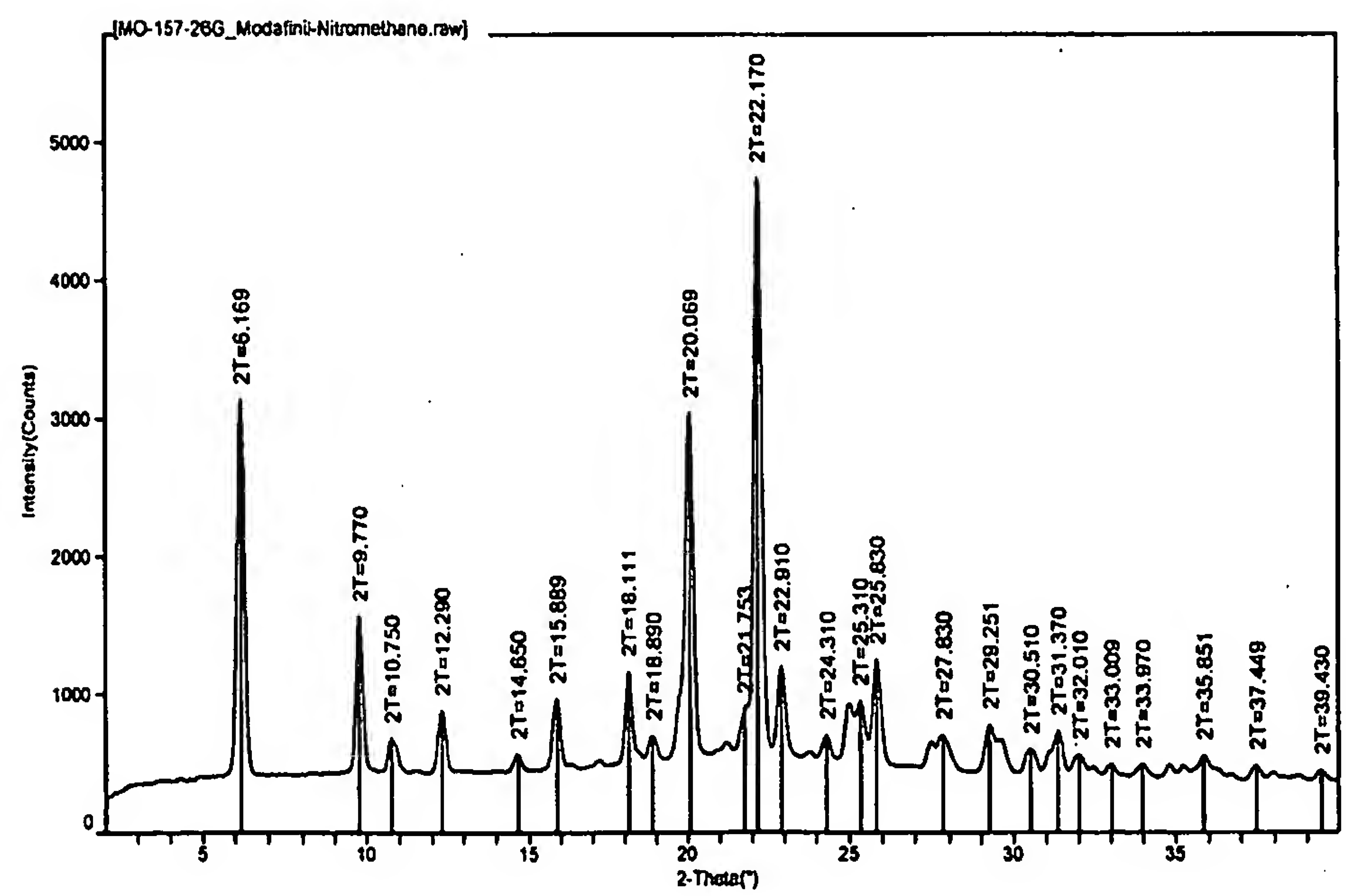


Figure 45

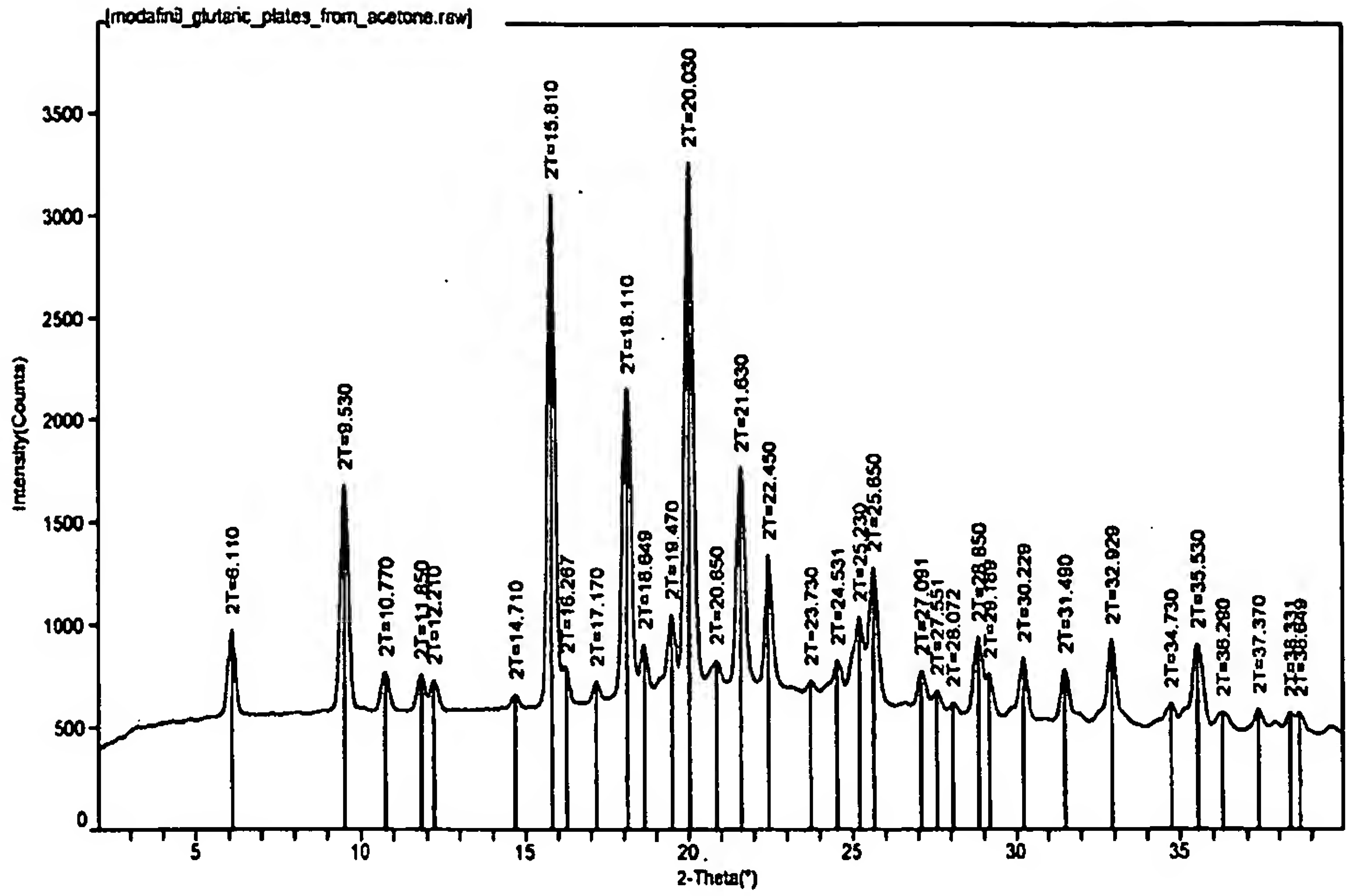


Figure 46

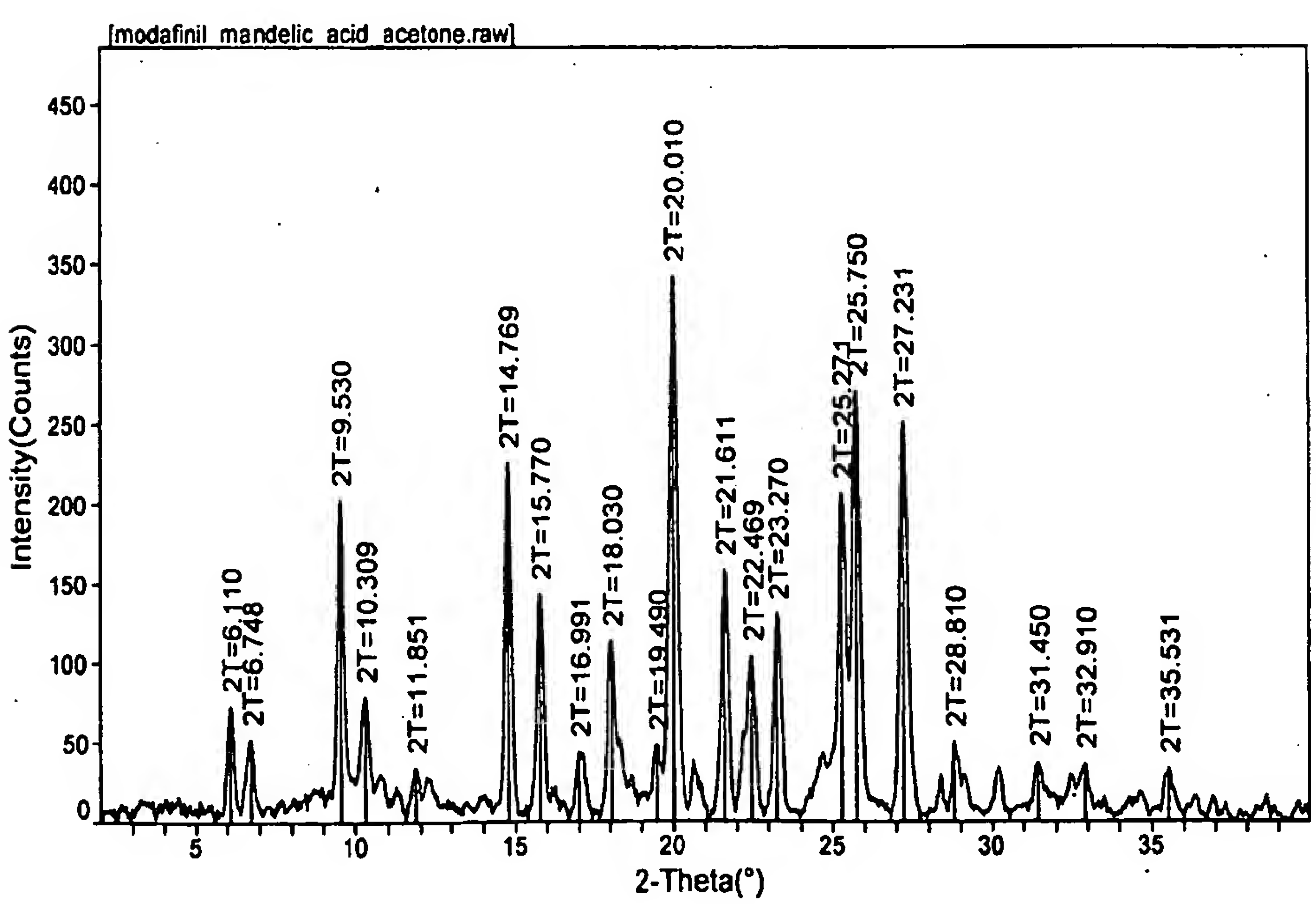
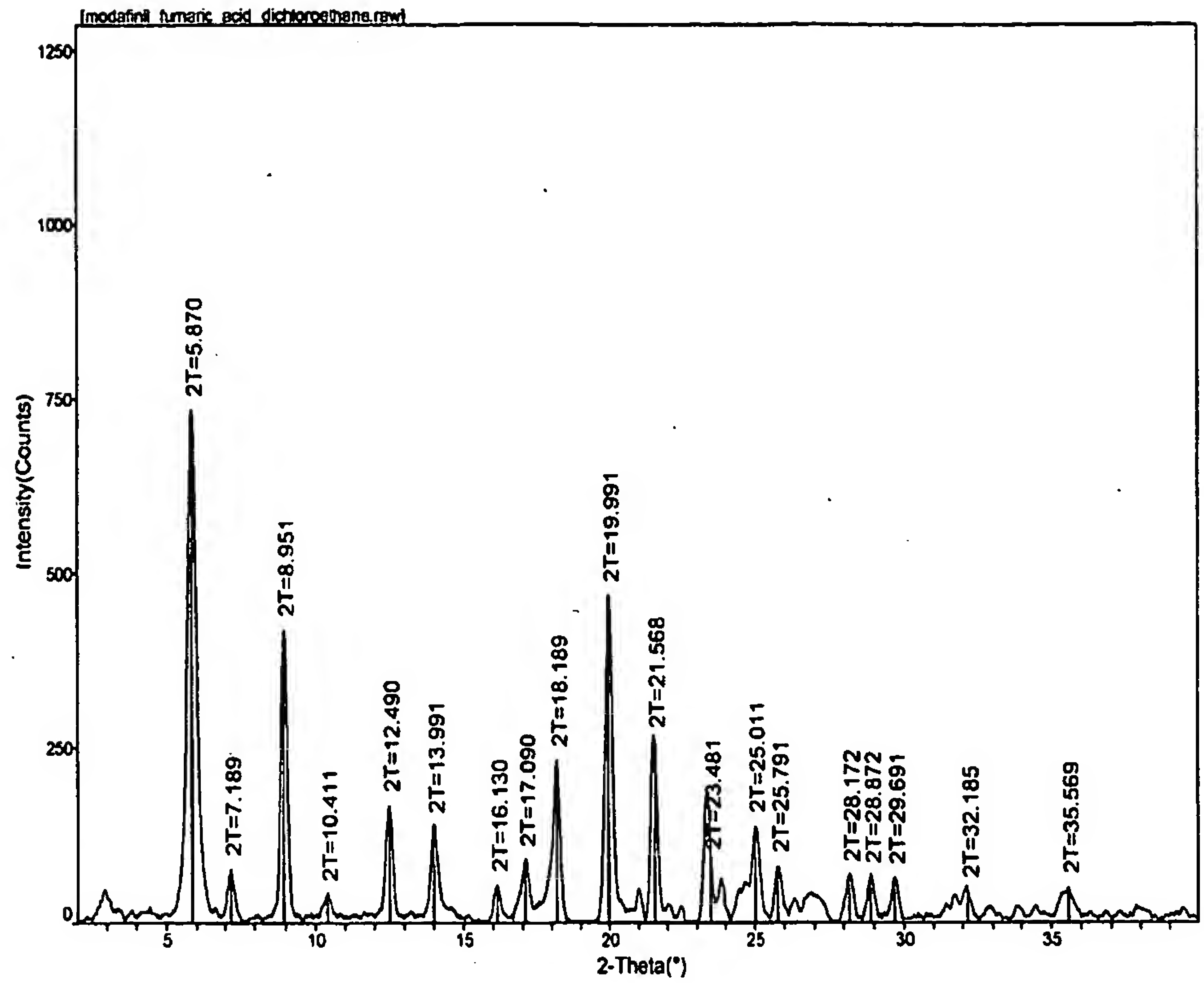


Figure 47



[modafinil fumaric acid dichloroethane.raw]
Intensity(Counts)
2-Theta(°)
2T=5.870
2T=7.189
2T=8.951
2T=10.411
2T=12.490
2T=13.991
2T=16.130
2T=17.090
2T=18.189
2T=19.991
2T=21.568
2T=23.481
2T=25.011
2T=25.791
2T=28.172
2T=28.872
2T=29.691
2T=32.185
2T=35.569

Figure 48

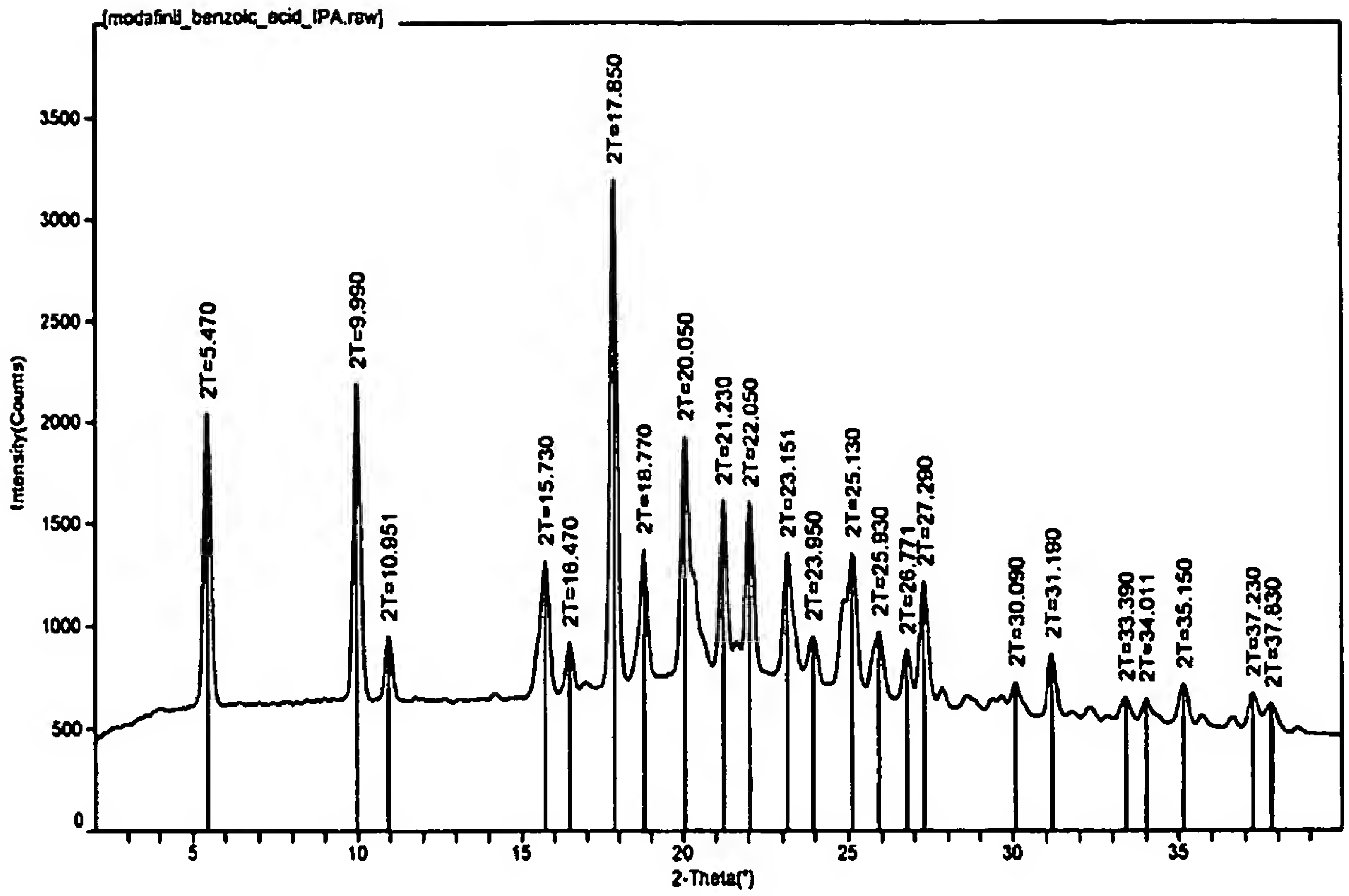


Figure 49

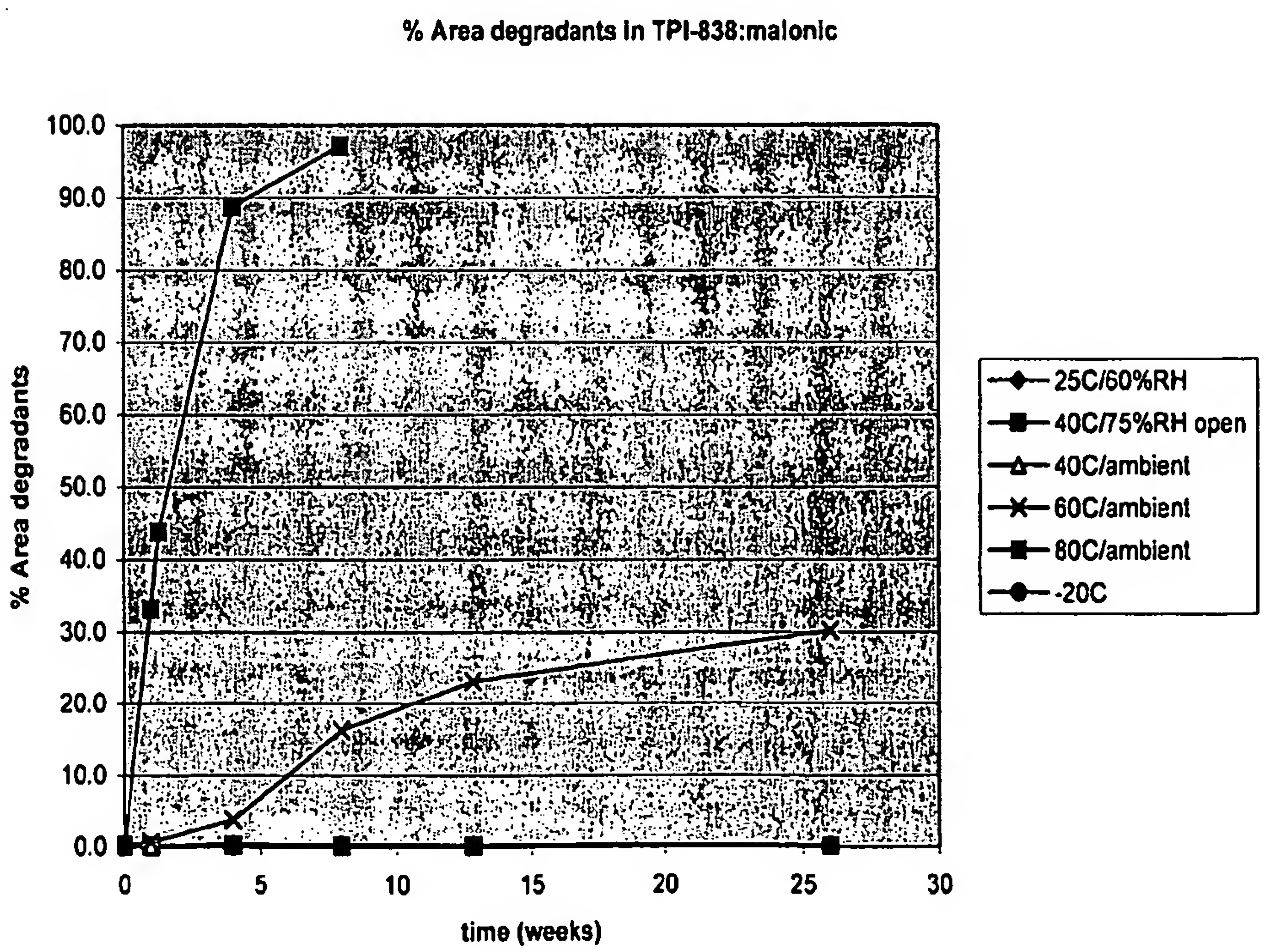


Figure 50

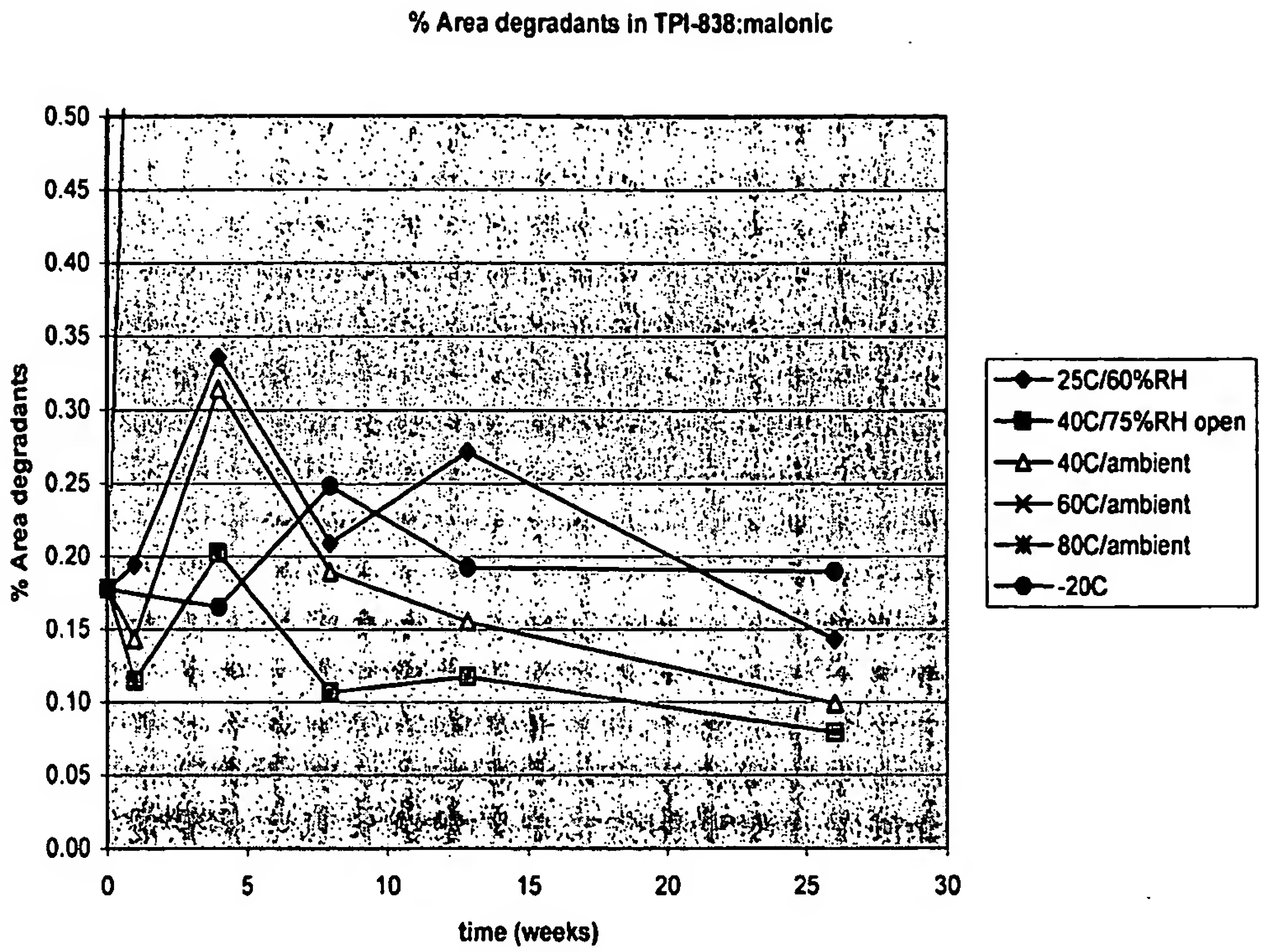

% Area degradants in TPI-838:malonic
% Area degradants
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
5
10
15
20
25
30
time (weeks)
25C/60%RH
40C/75%RH open
40C/ambient
60C/ambient
80C/ambient
-20C

Figure 51

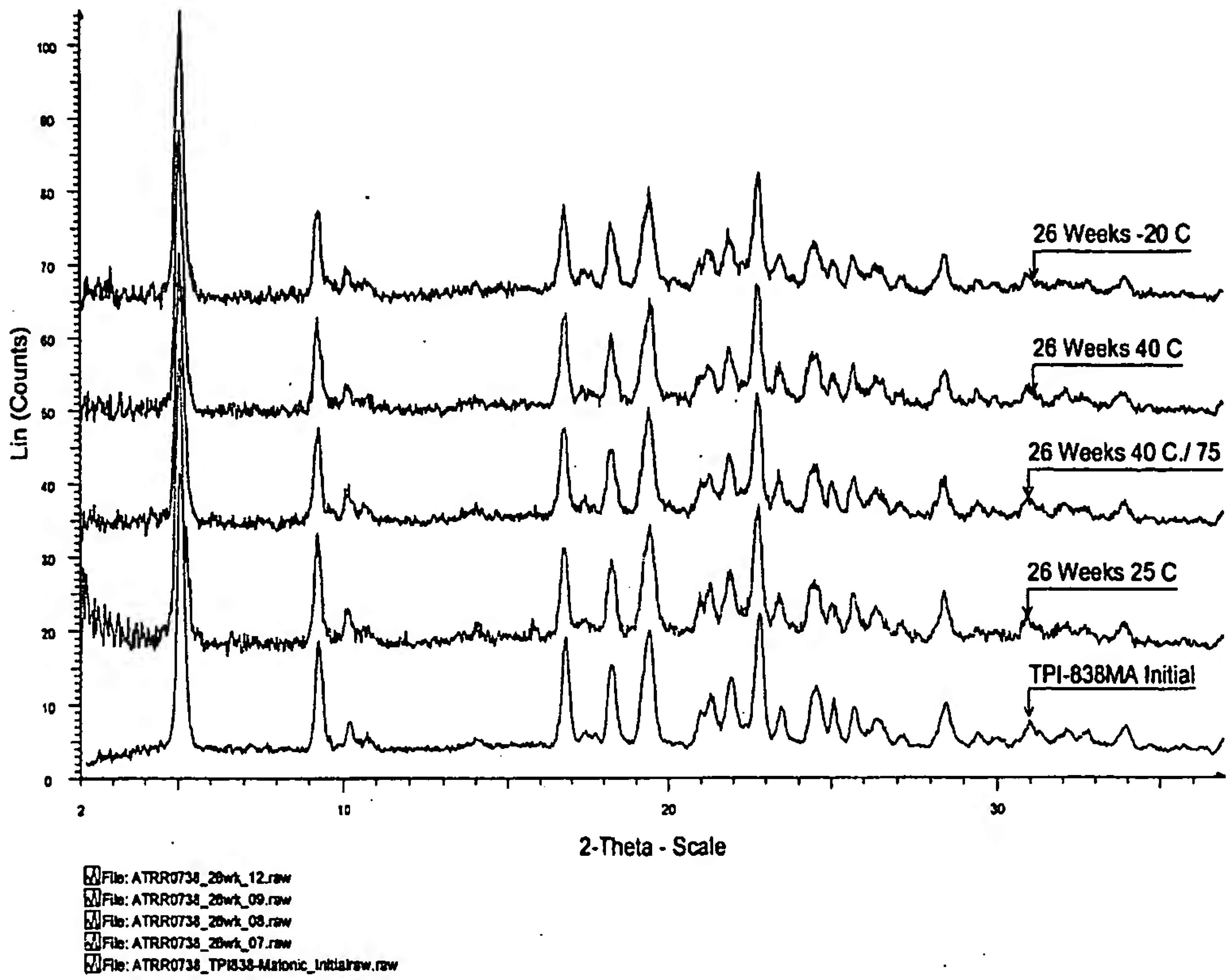

Lin (Counts)
2-Theta - Scale
26 Weeks -20 C
26 Weeks 40 C
26 Weeks 40 C./ 75
26 Weeks 25 C
TPI-838MA Initial
File: ATRR0738_26wk_12.raw
File: ATRR0738_26wk_09.raw
File: ATRR0738_26wk_08.raw
File: ATRR0738_26wk_07.raw
File: ATRR0738_TPI838-Malonic_Initialraw.raw

Figure 52

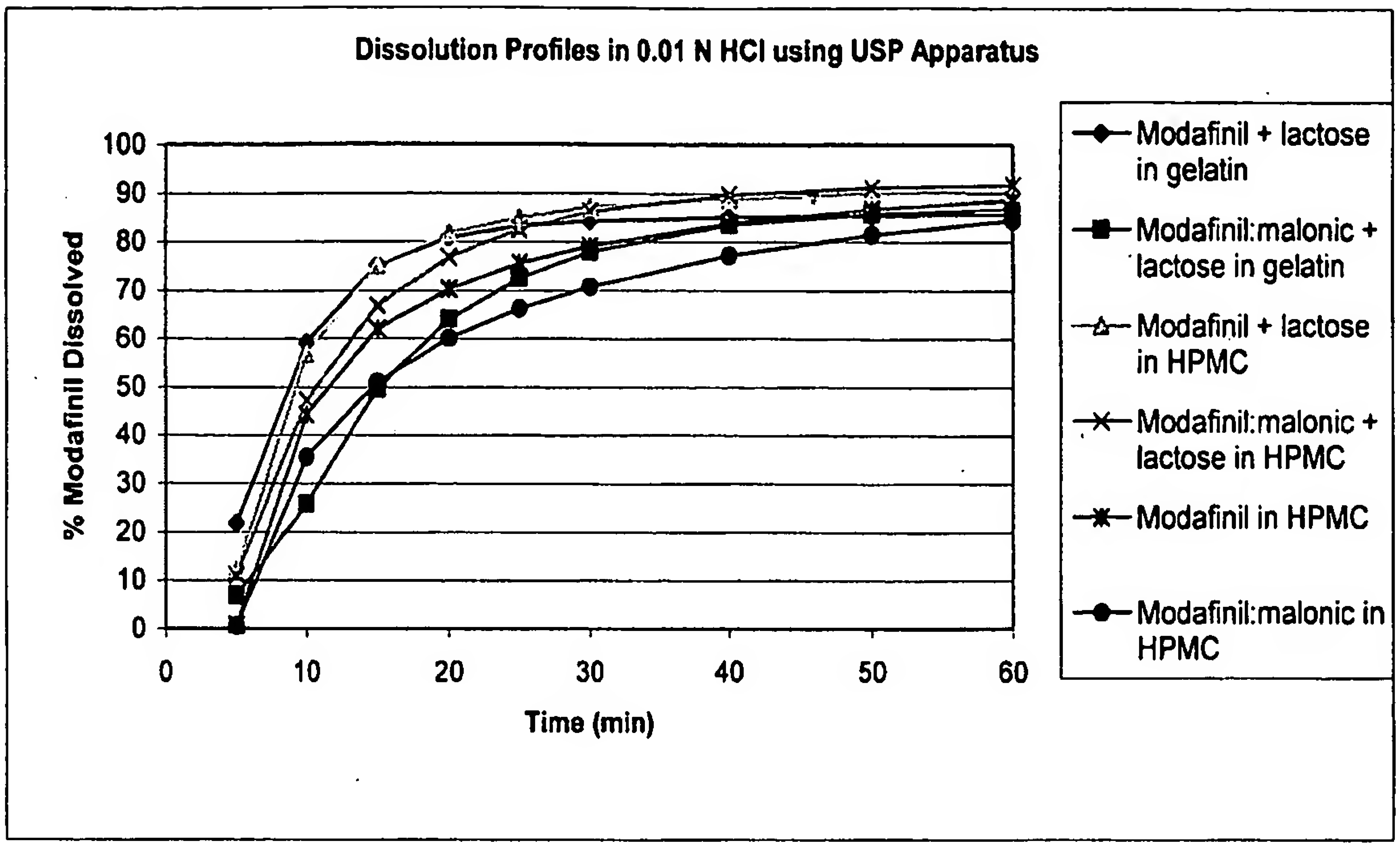


Figure 53

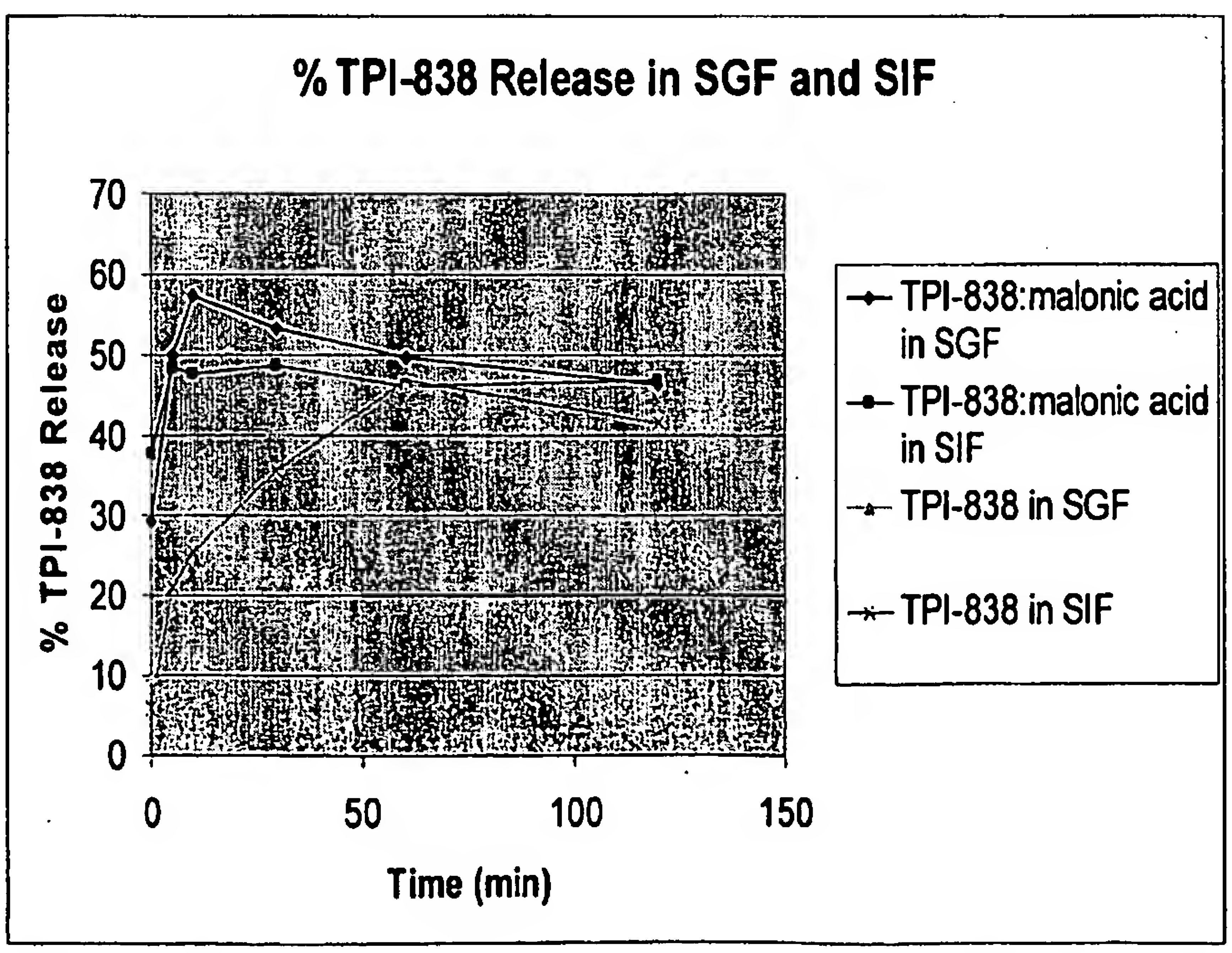


Figure 54

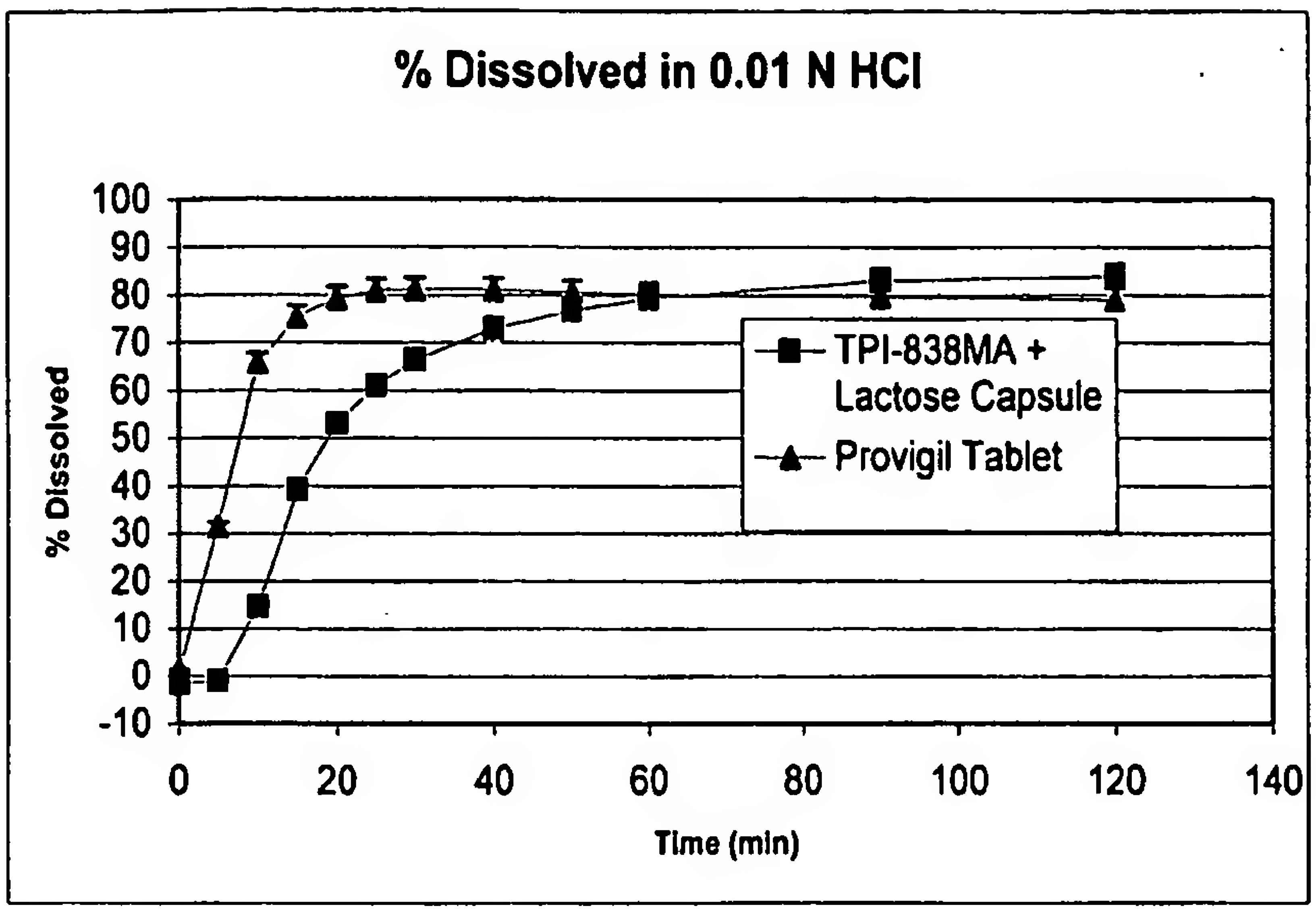


Figure 55

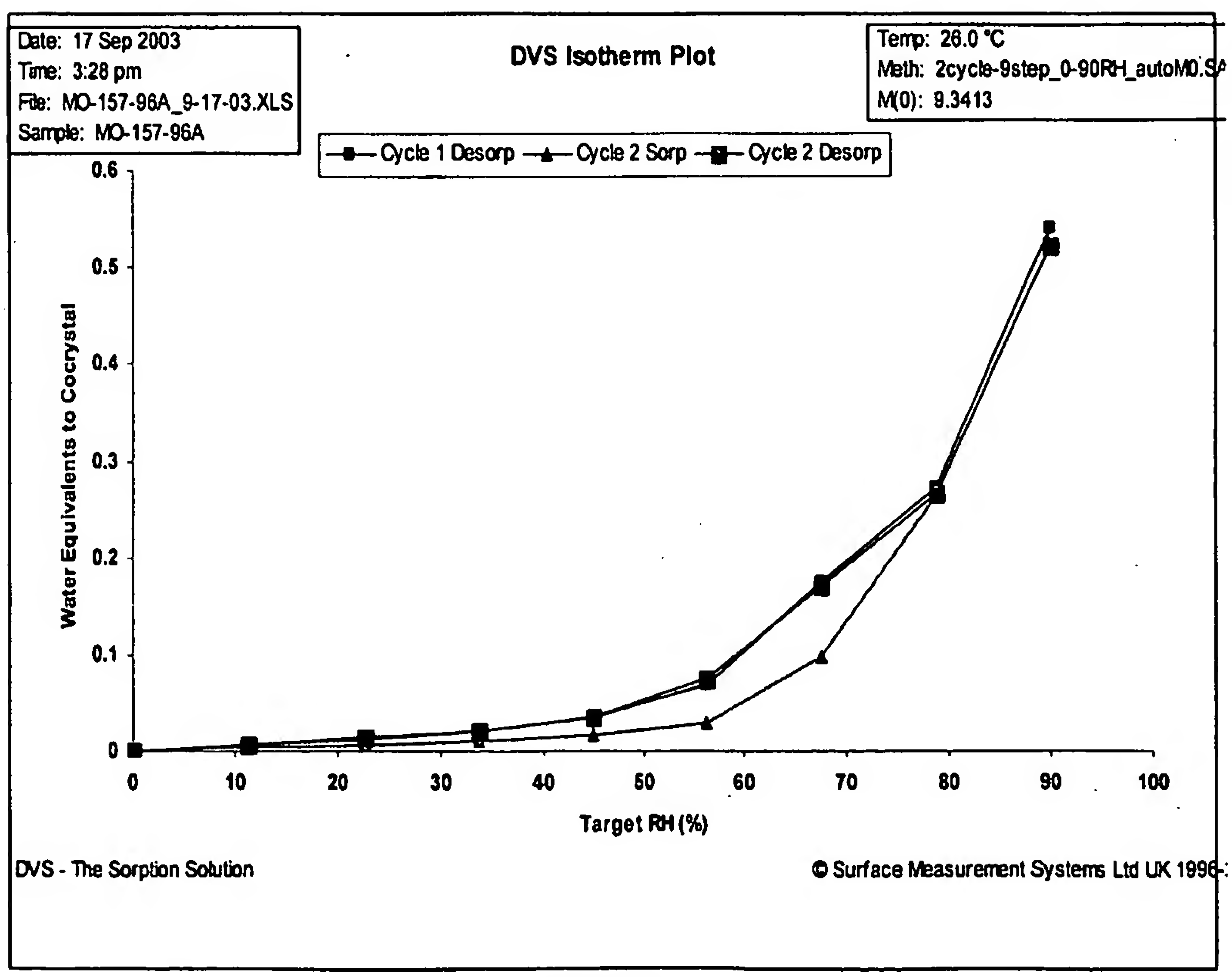


Figure 56

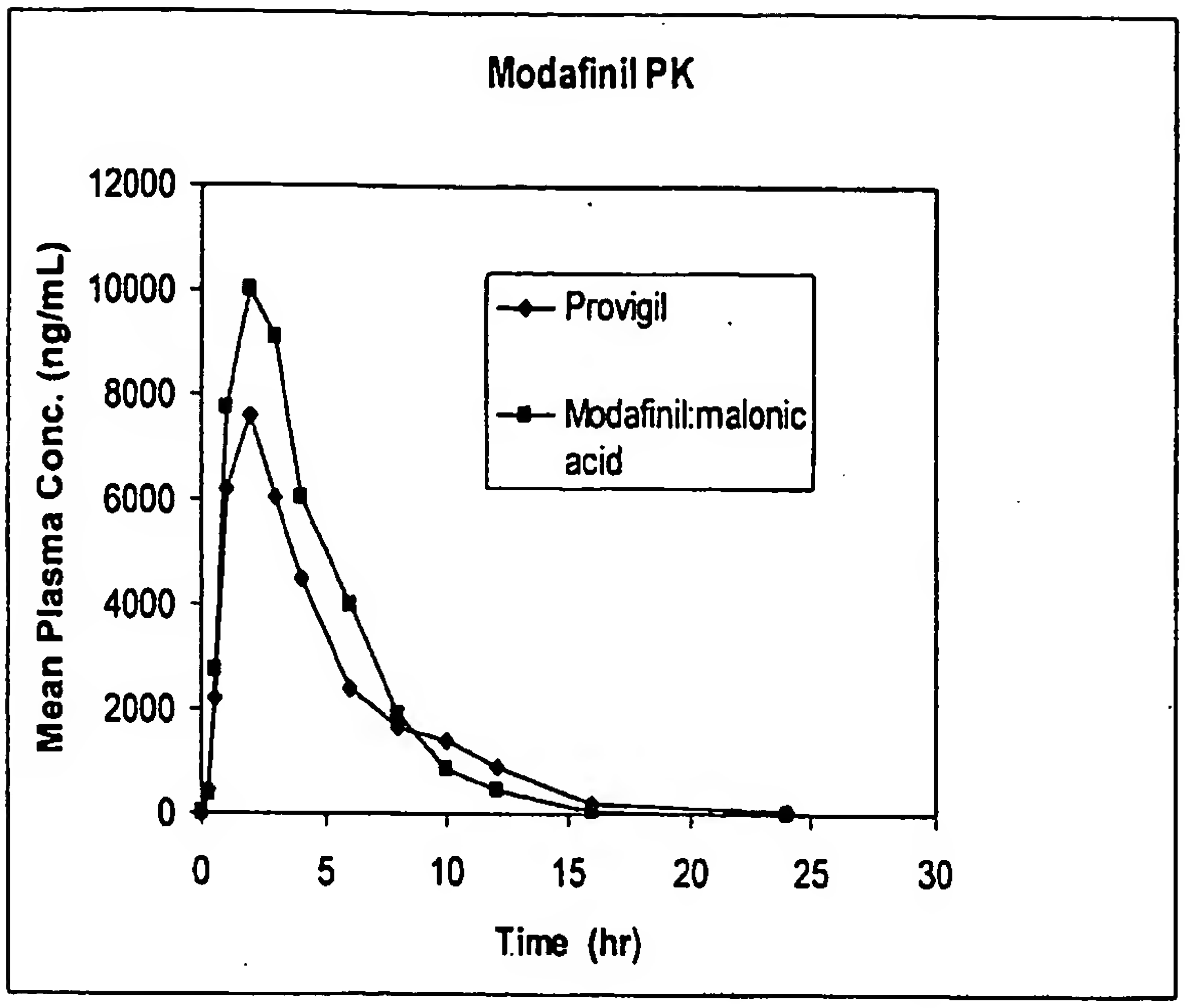


Figure 57

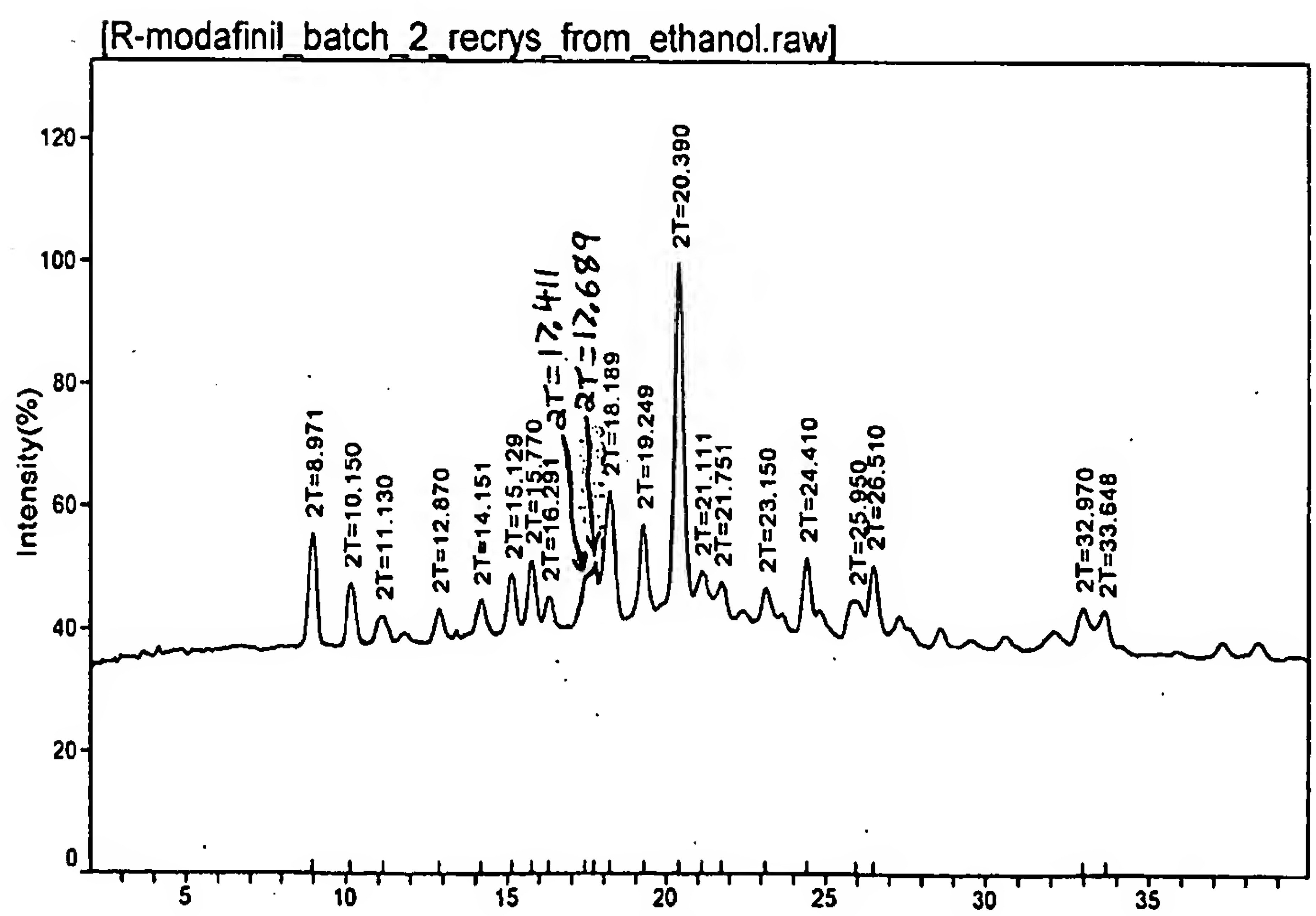


Figure 58

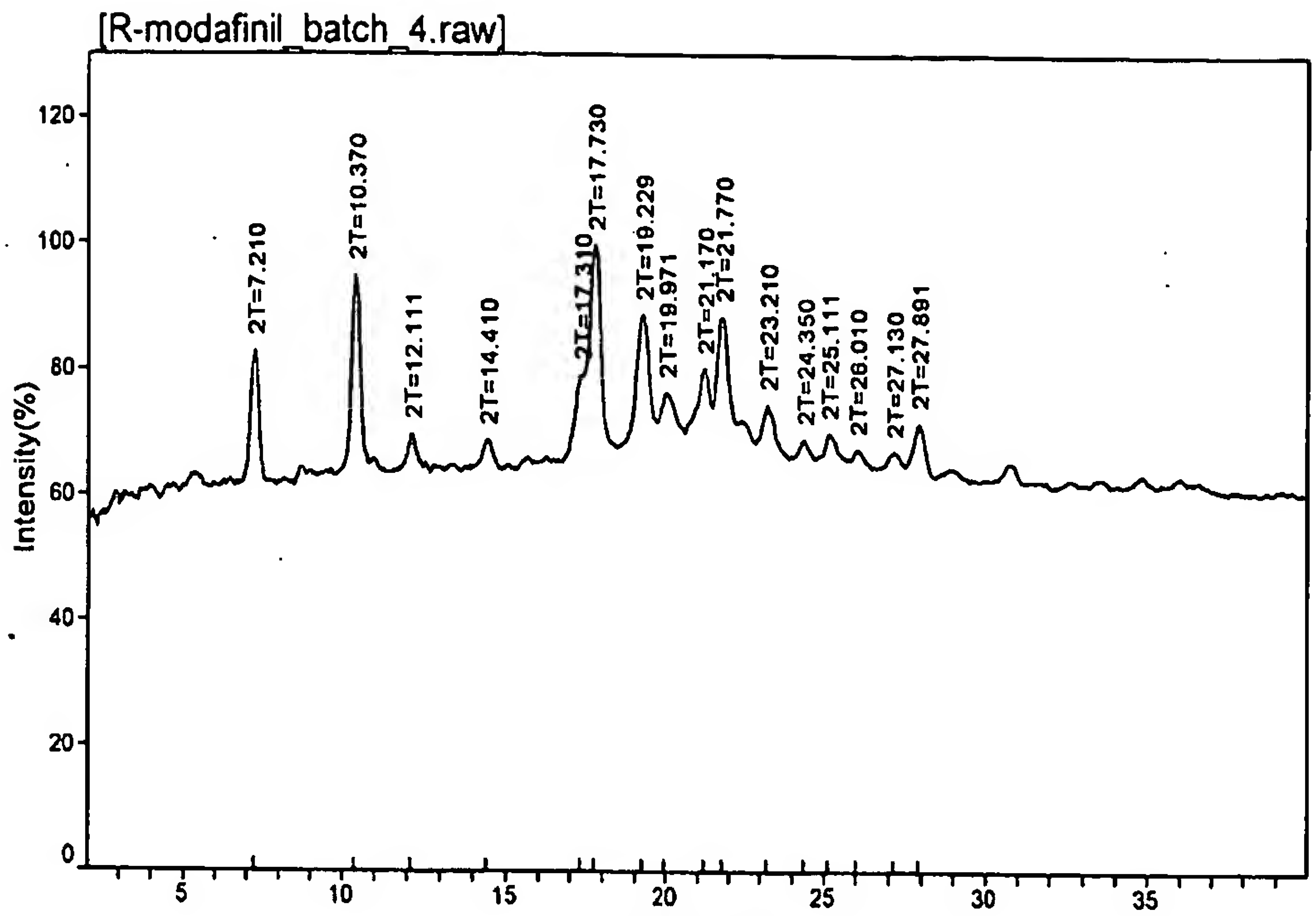


Figure 59

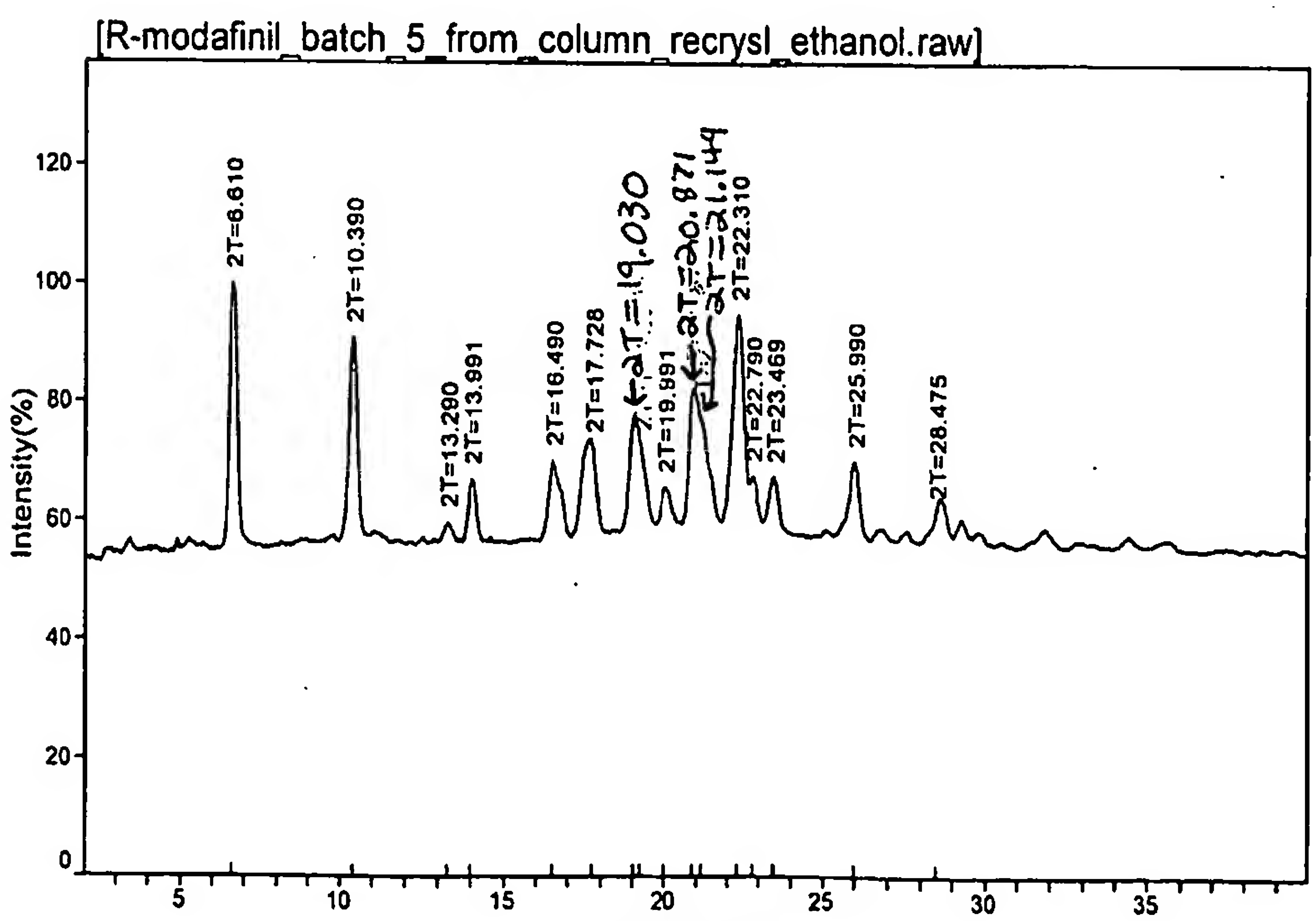


Figure 60

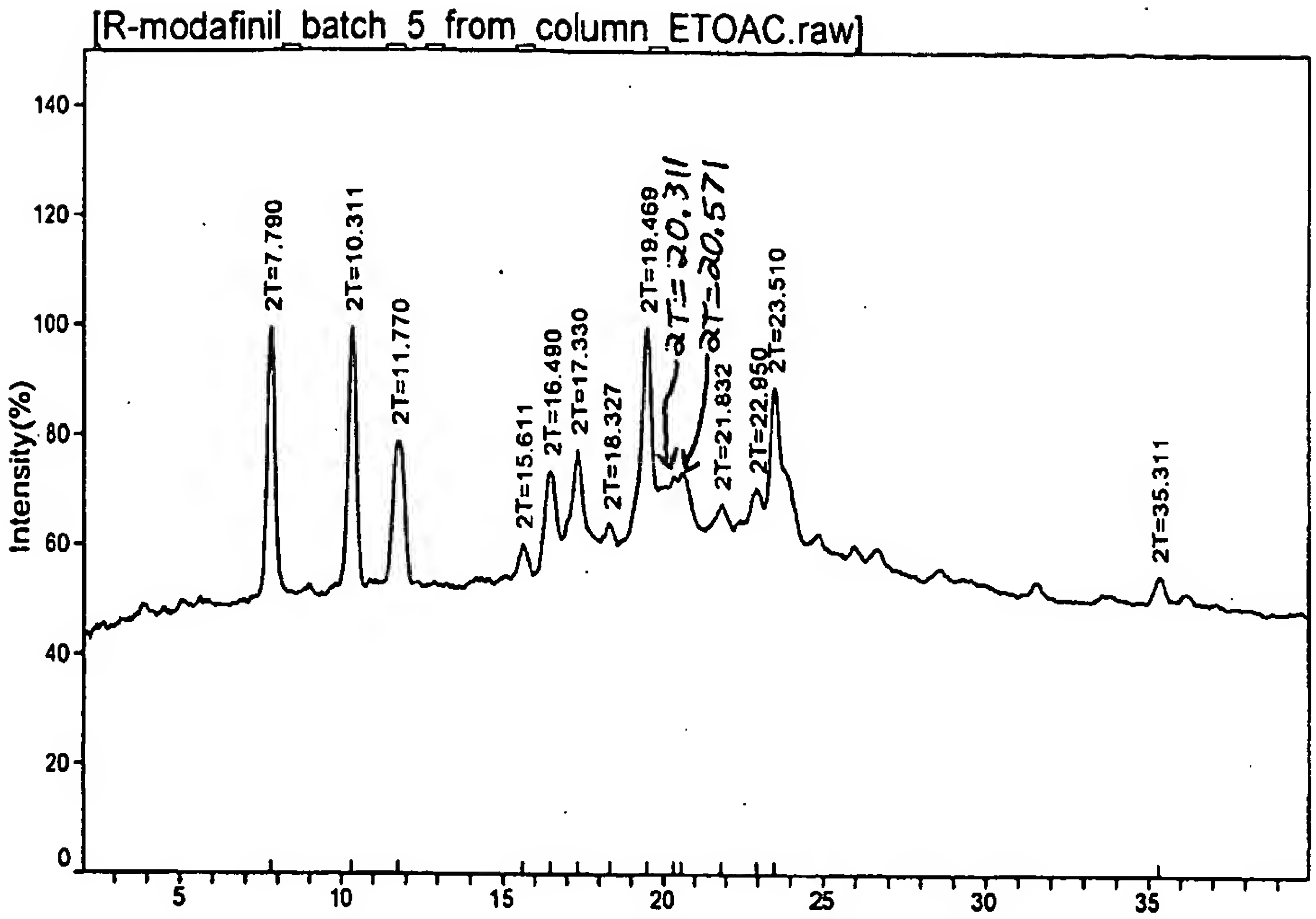


Figure 61

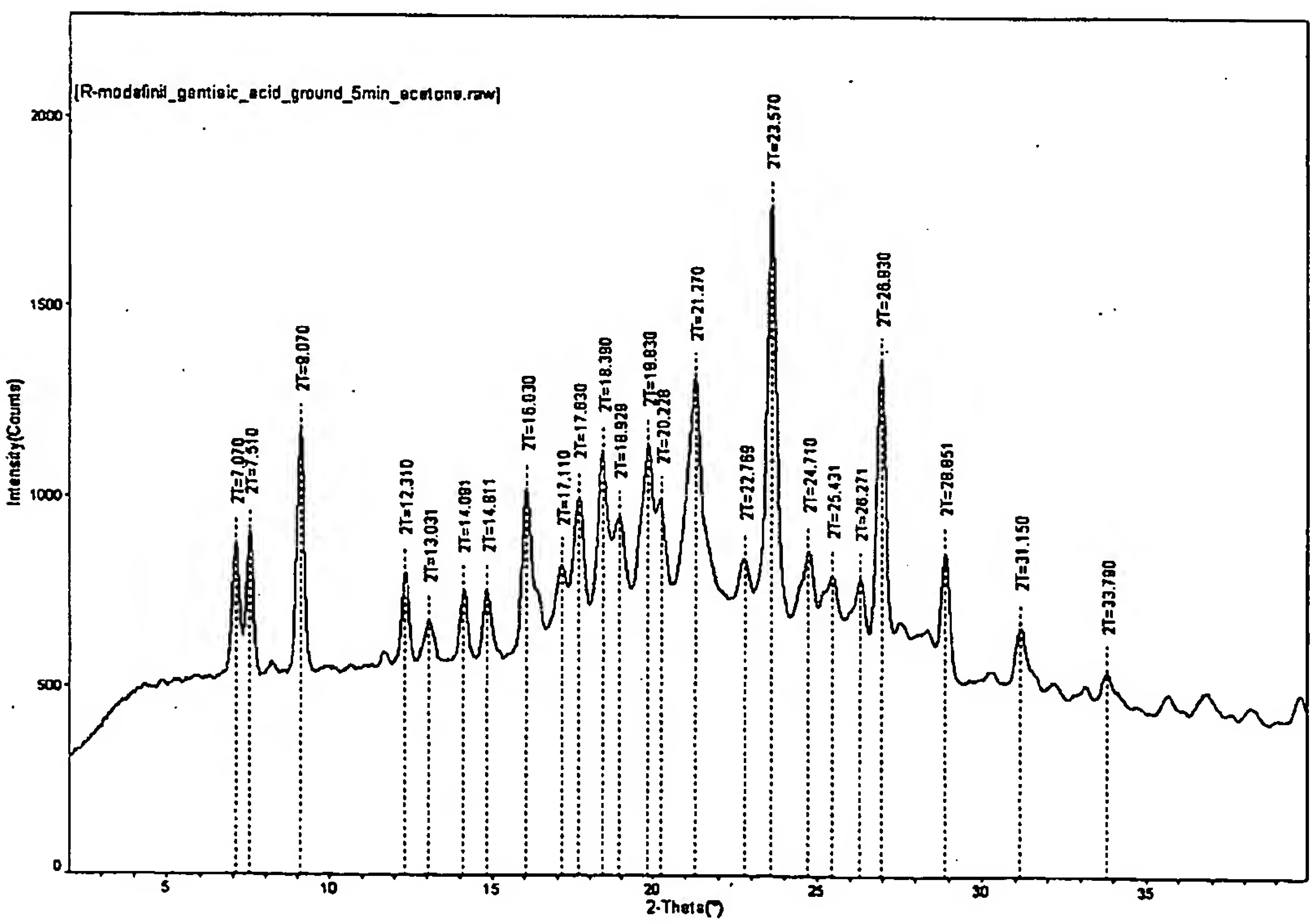


Figure 62

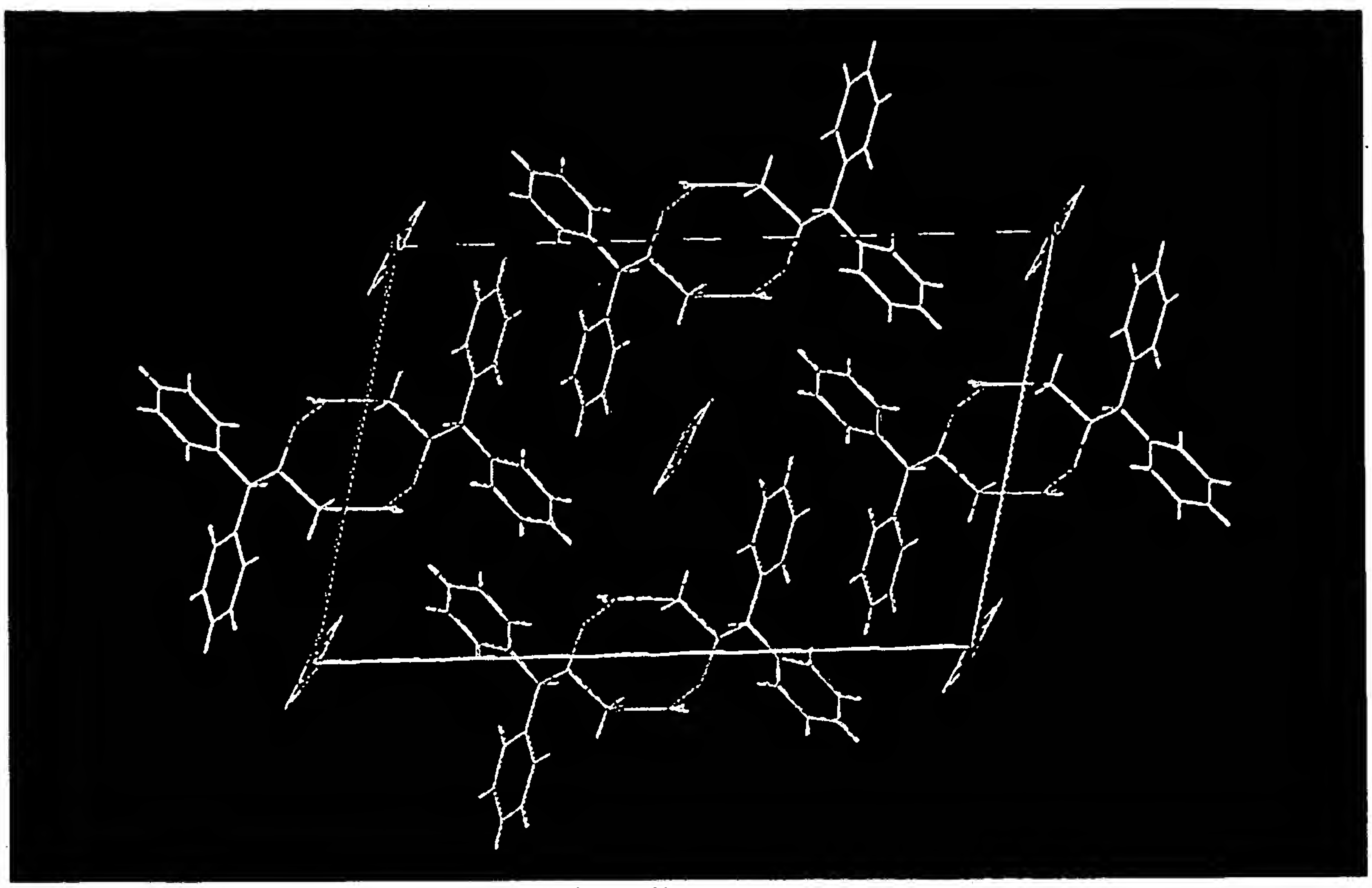


Figure 63

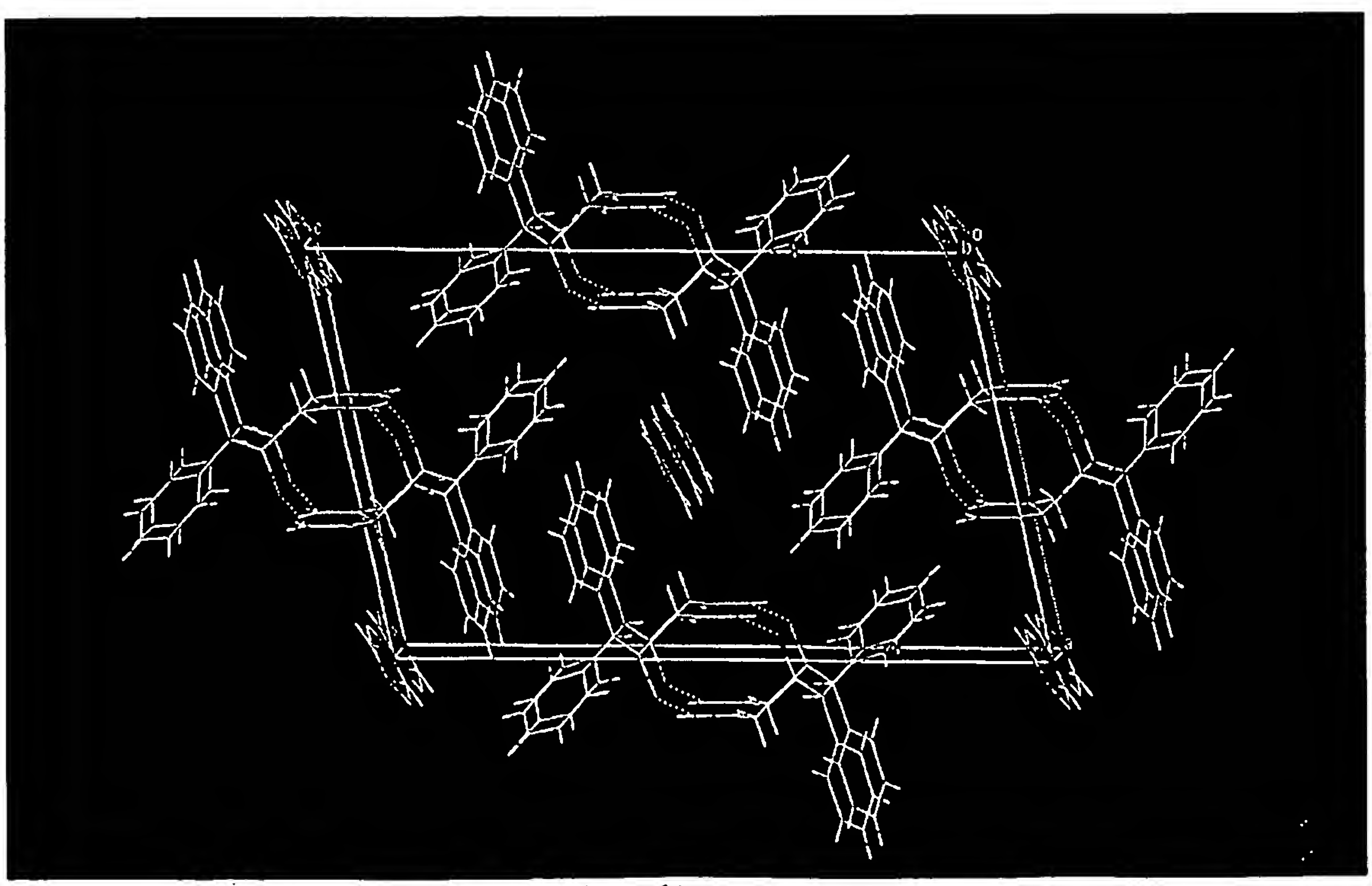


Figure 64

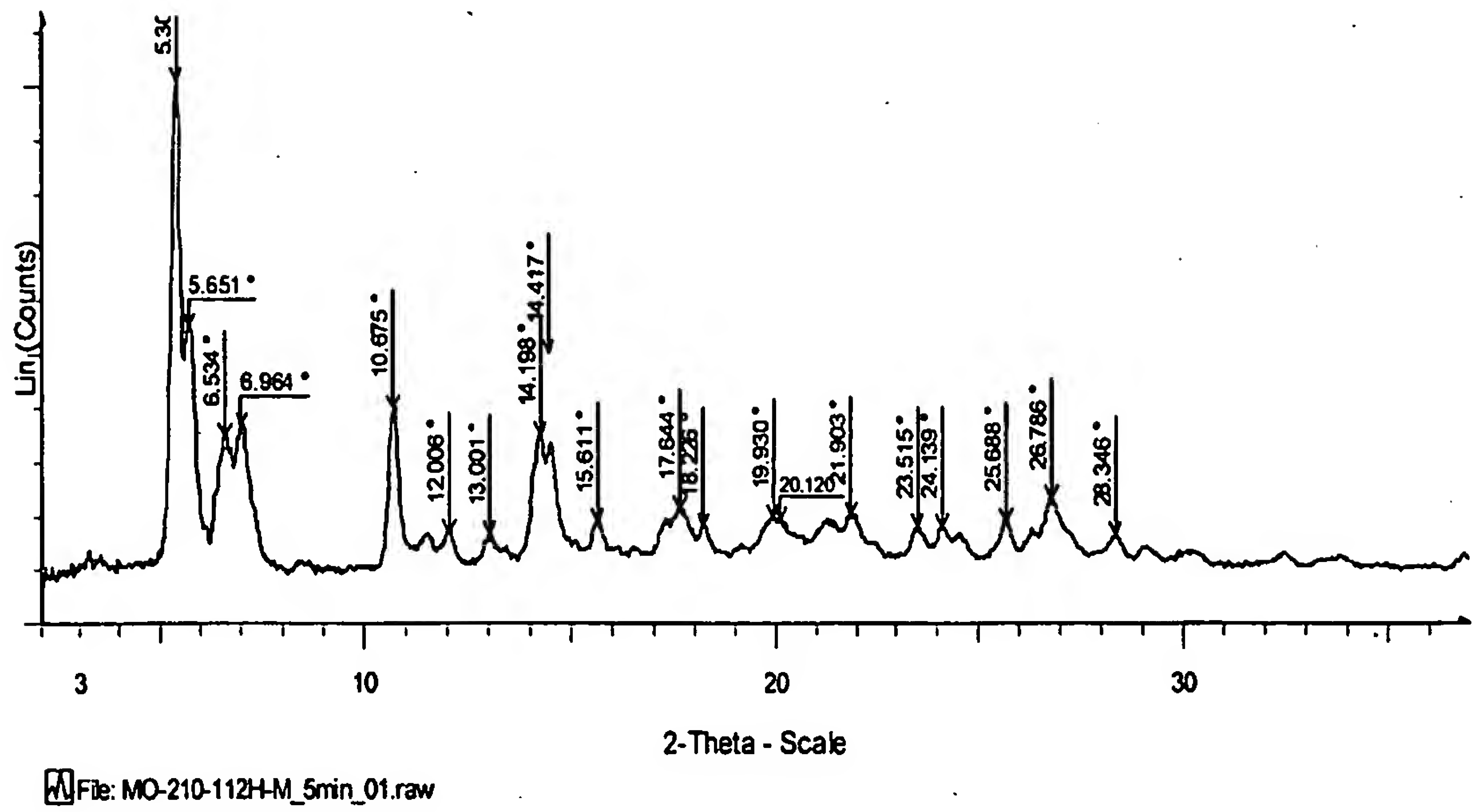


Figure 65

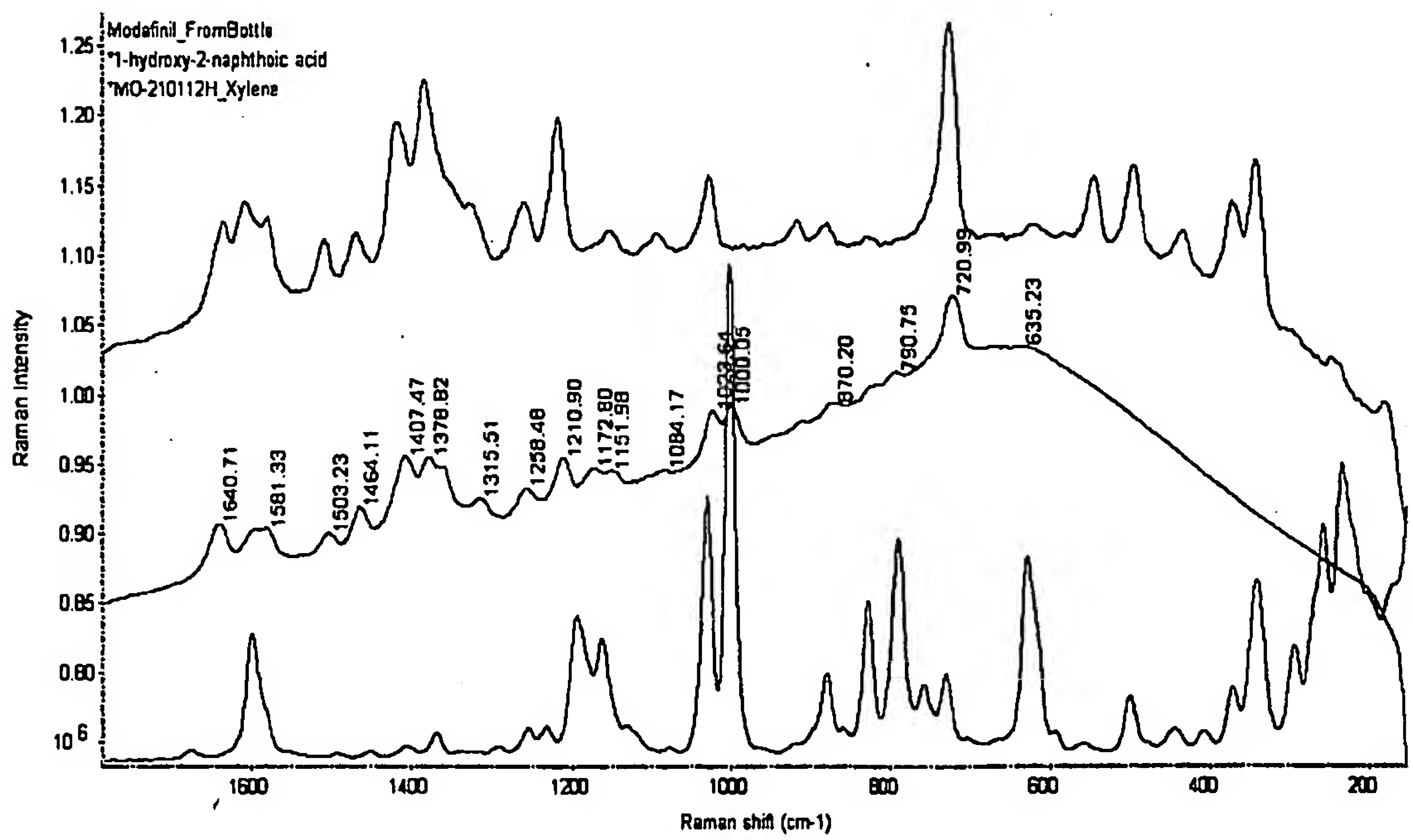


Figure 66

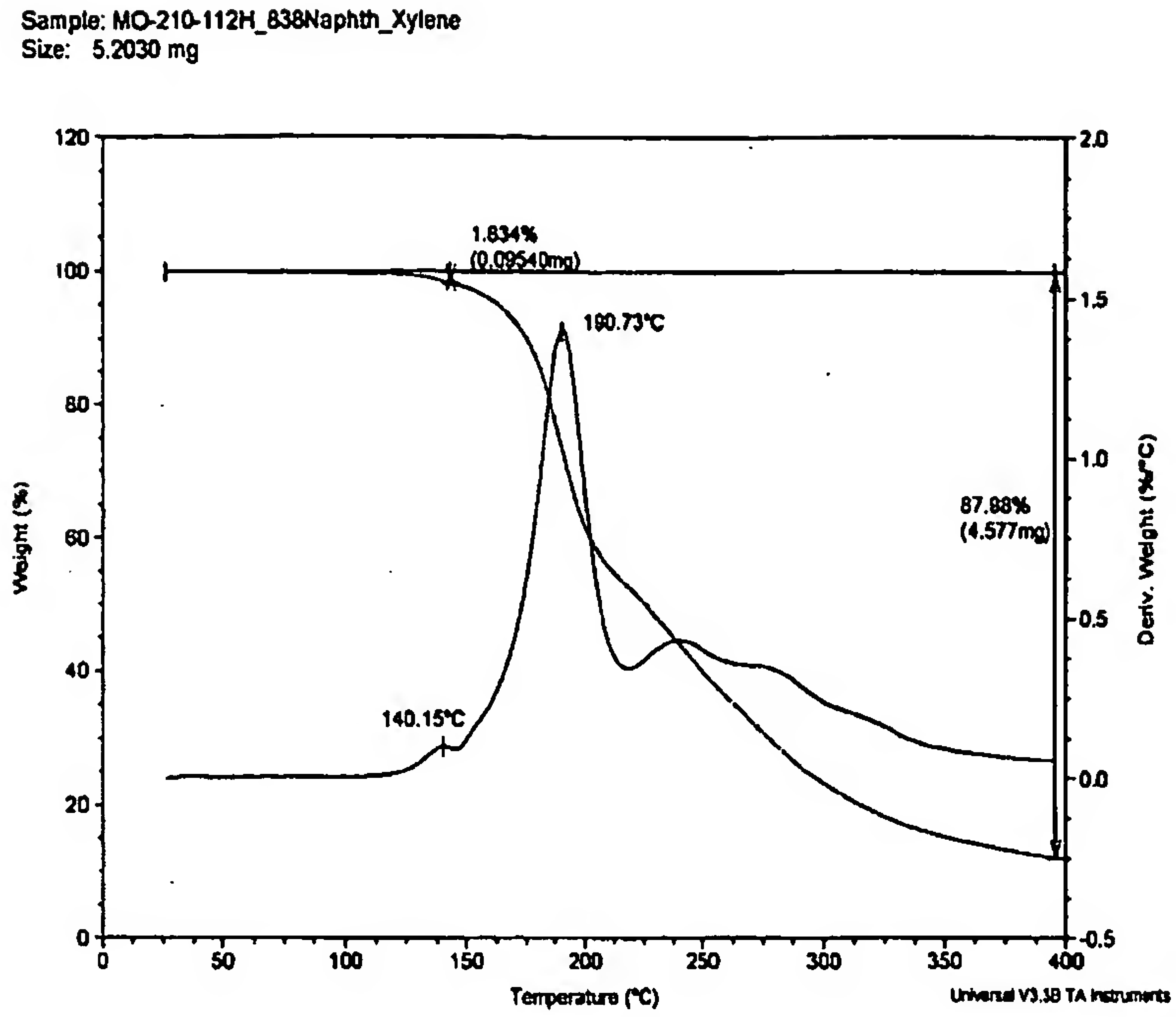


Figure 67

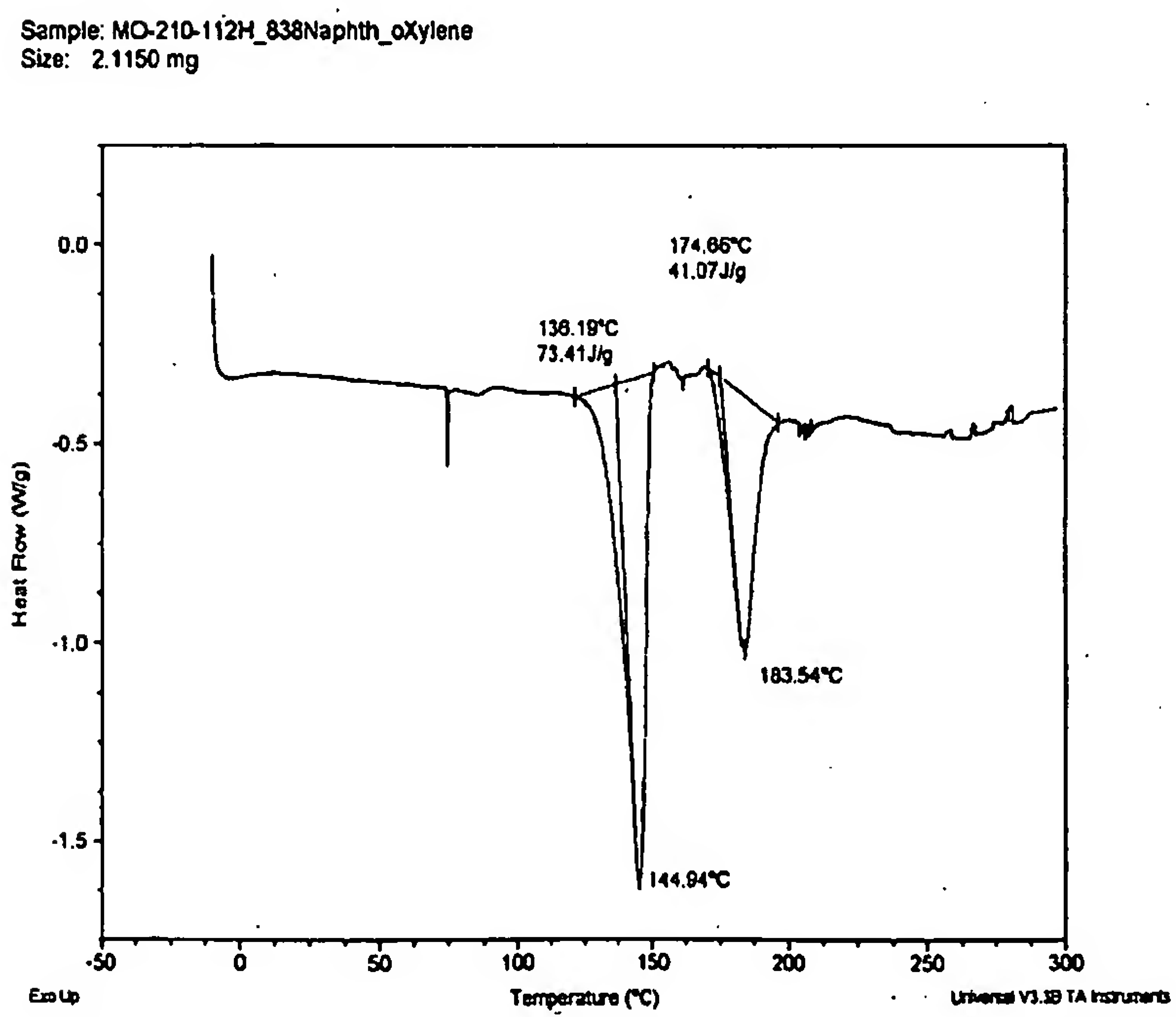


Figure 68

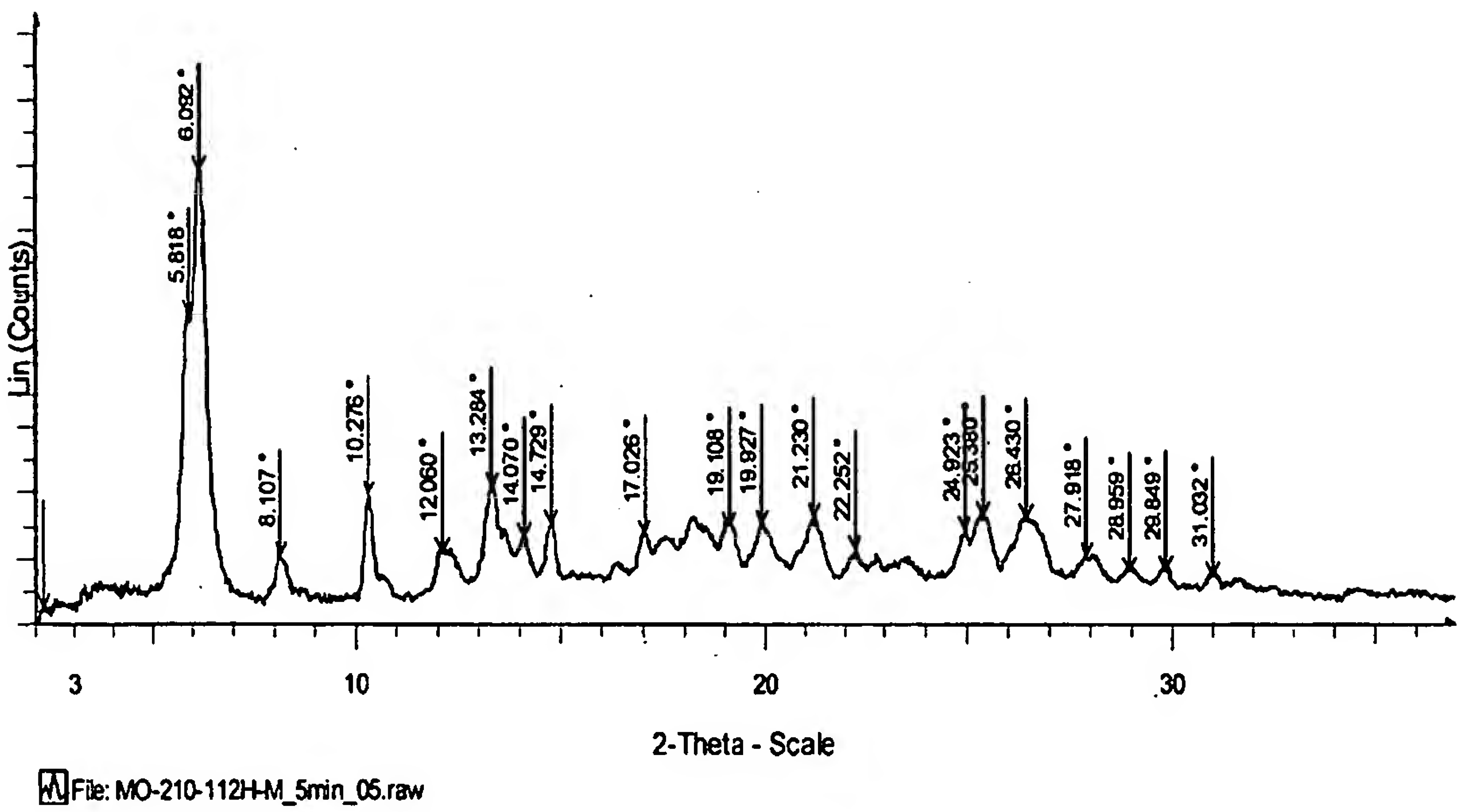


Figure 69

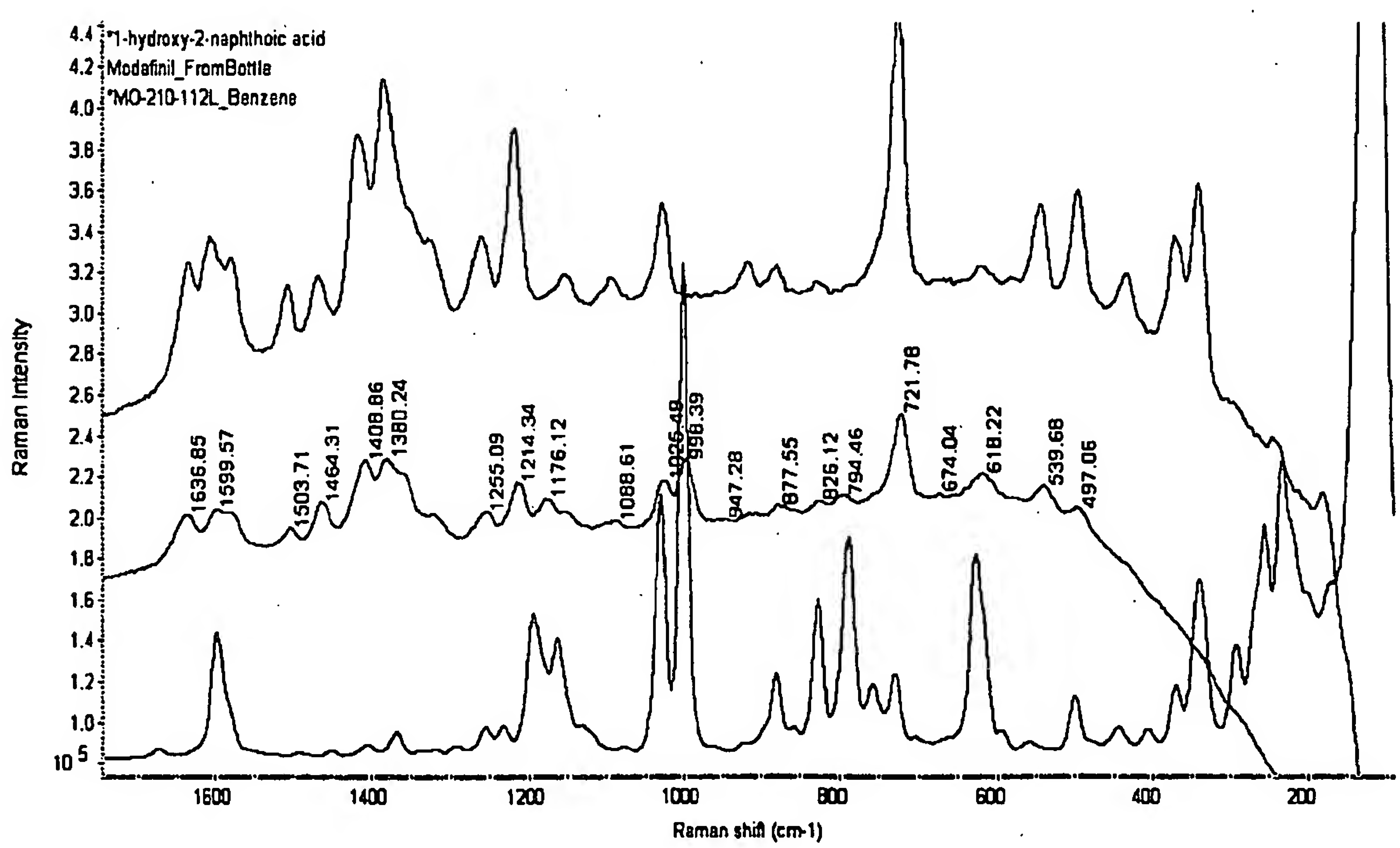


Figure 70

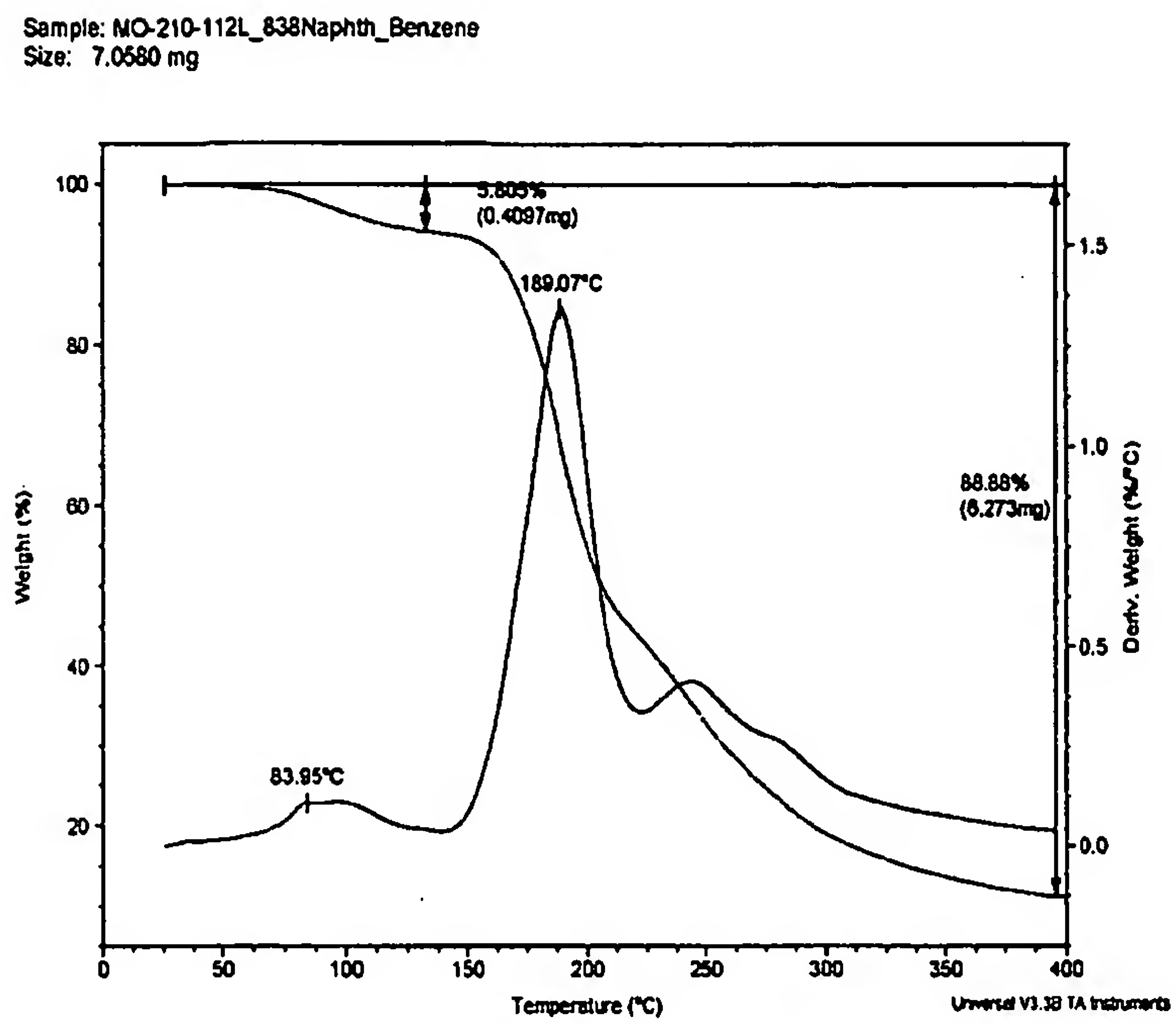


Figure 71

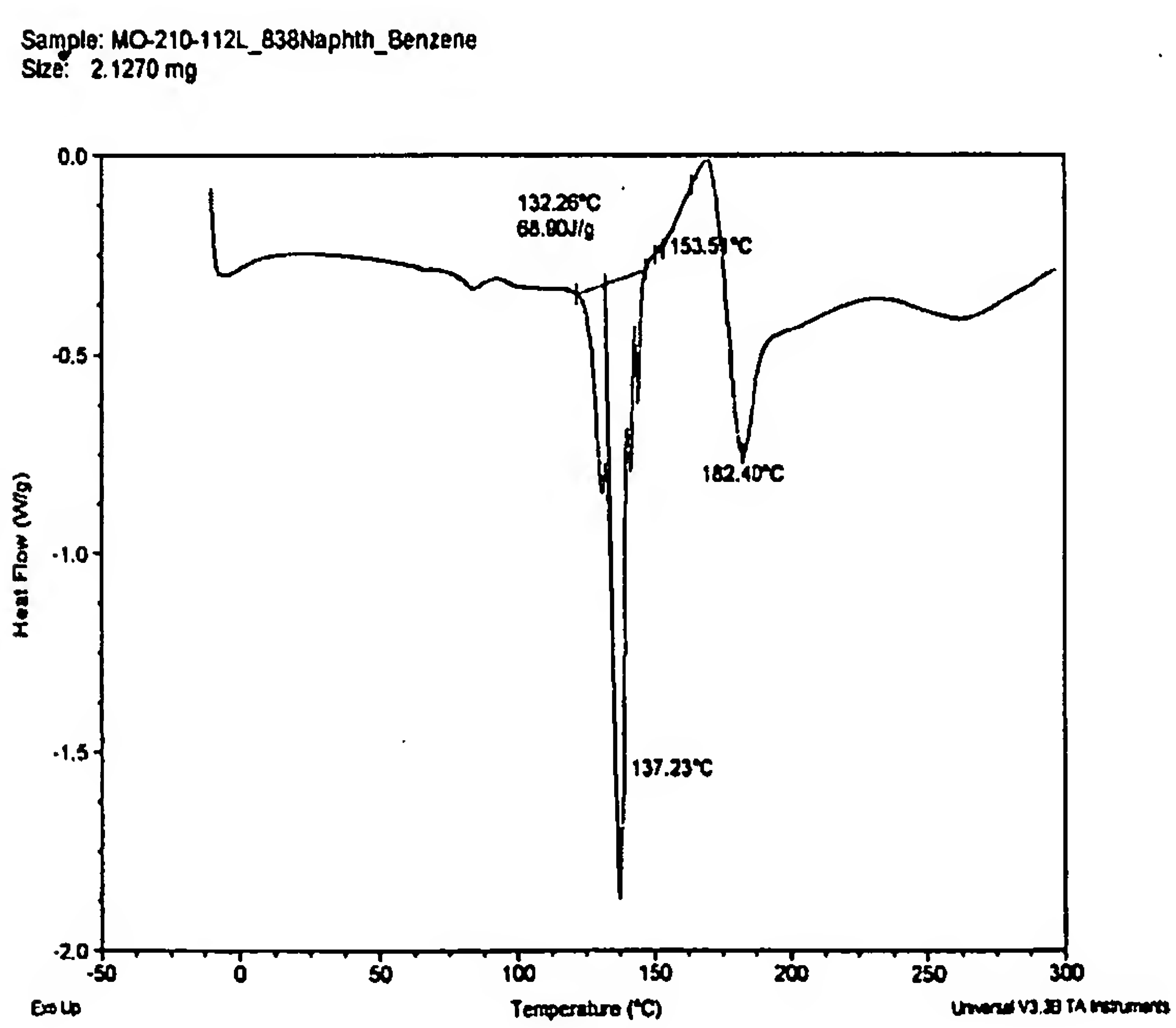


Figure 72

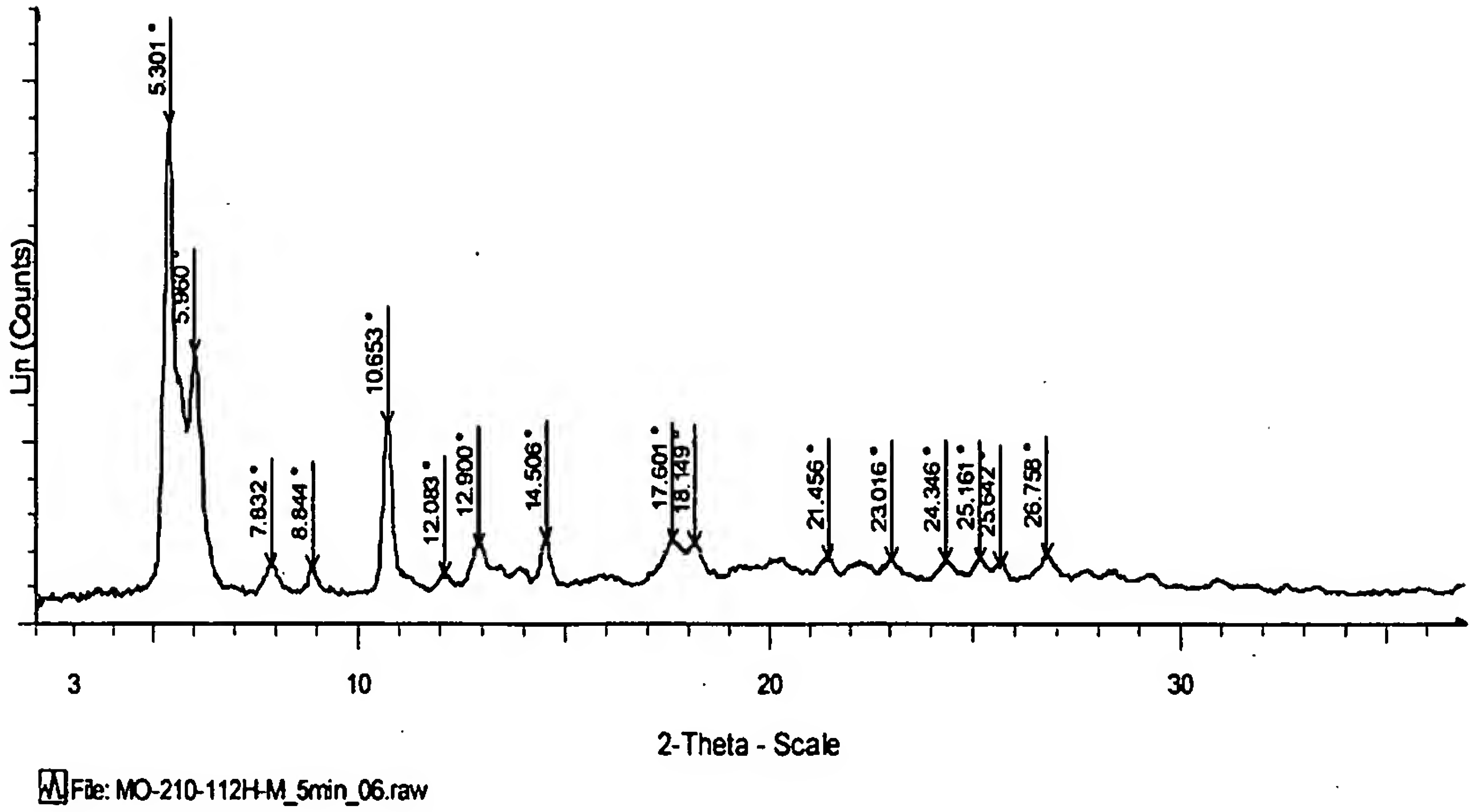


Figure 73

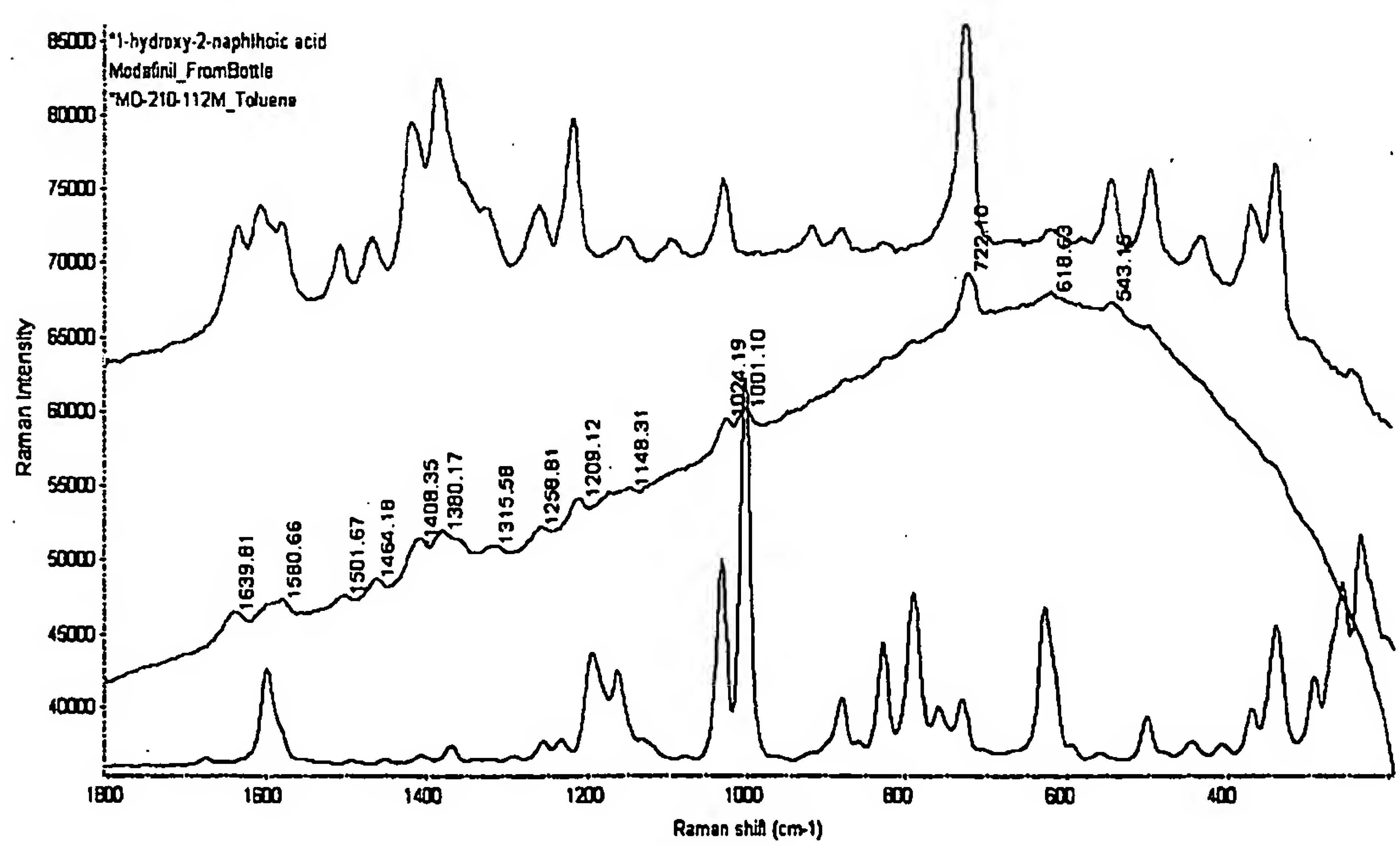


Figure 74

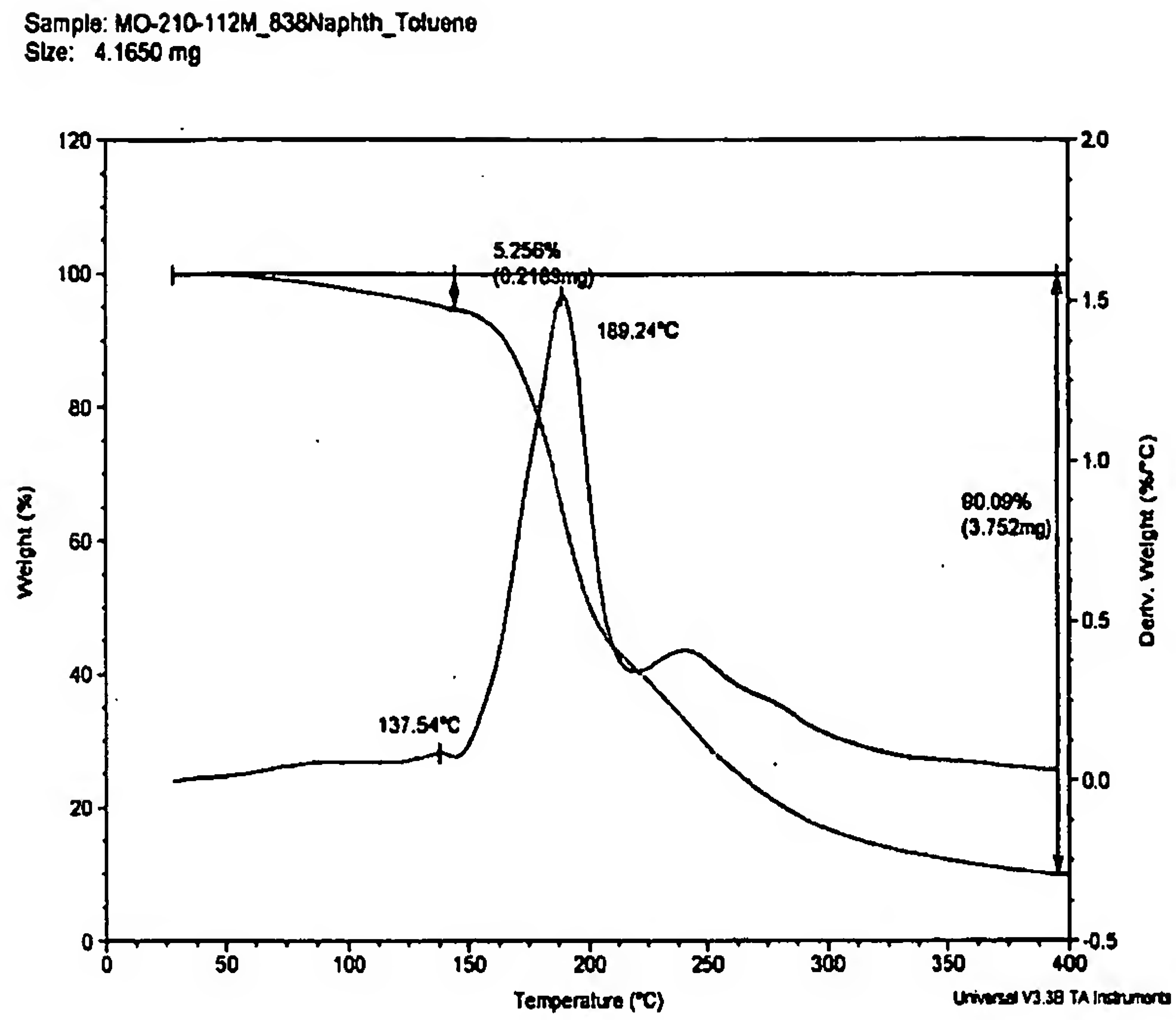


Figure 75

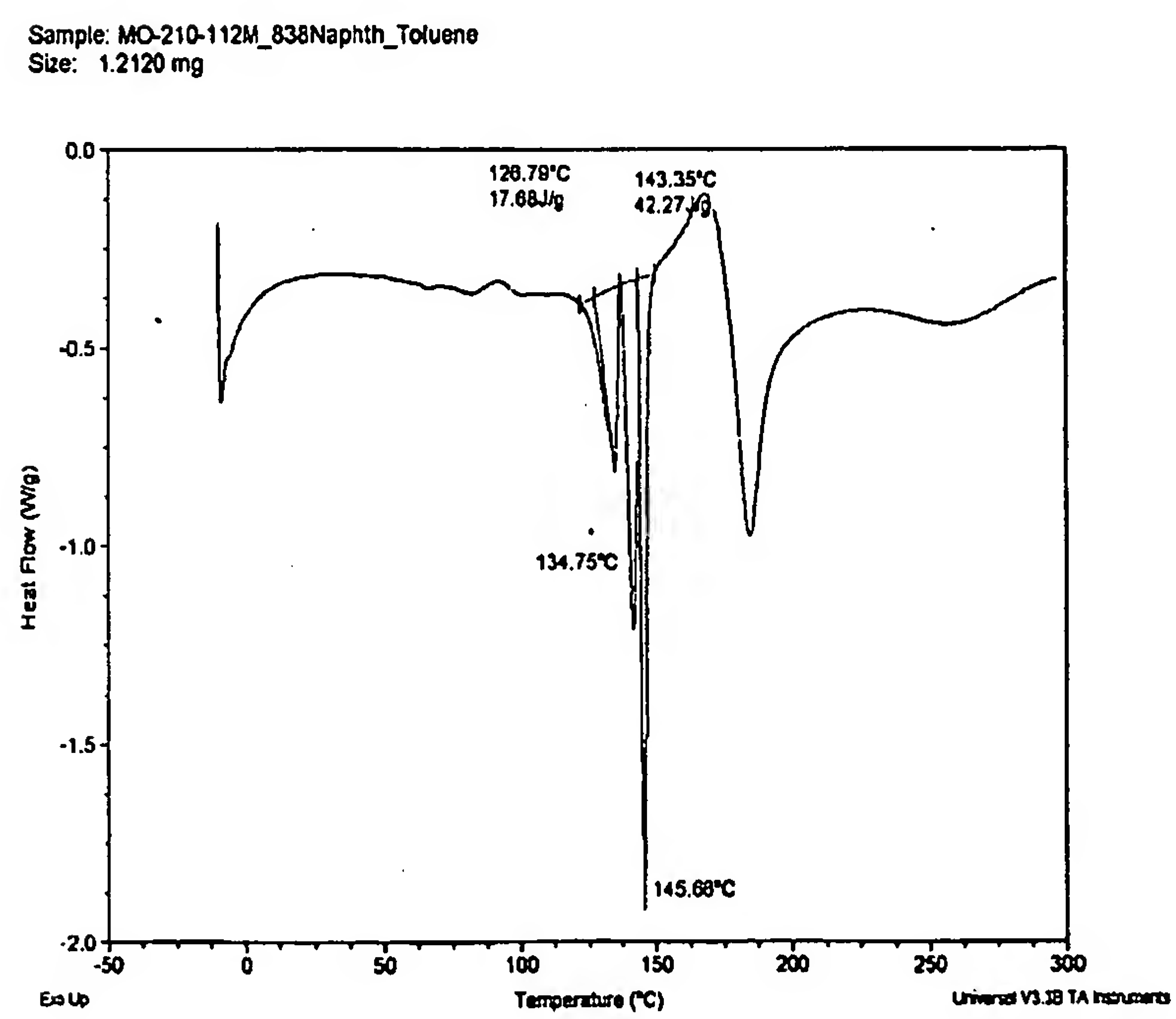


Figure 76